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ABSTRACT

This learning module aims to engage students in problem solving, critical thinking, scientific inquiry, and cooperative learning. The module is appropriate for use in any introductory or intermediate undergraduate course that focuses on human-environment relationships. The module explains that land use/cover change has occurred at all times in all parts of the world, and that most affected and involved in these processes are the environmental spheres of water, soil, and vegetative cover, which are closely linked to geomorphology, climate, fauna, and especially human societies. According to the module, the most profound questions with respect to land use/cover and global change are: what forces drive land use/land cover change?; what impacts do these changes have on the environment and on human society?; and how might people respond to them most effectively? The module introduces students to the complexities inherent in these questions, focusing mainly on the first. The module contains 8 tables, 13 figures, a list of acronyms, a guide, a summary, an overview, references for all units, supporting materials, and readings. It is divided into thematically coherent; each unit consists of background information, teaching suggestions, student workshops, and the answers expected for each activity. (Author/BT)

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Human Driving Forces and their Impacts on Land Use/Land Cover

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An Active Learning Module on the Human Dimensions of Global Change

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HANDS-ON!

DEVELOPING ACTIVE
LEARNING MODULES ON THE
HUMAN DIMENSIONS OF GLOBAL CHANGE

Human Driving Forces and their Impacts on Land Use/Land Cover

Module developed for the AAG/CCG2 Project
"Developing Active Learning Modules on the Human Dimensions of Global Change"

by

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Developing Active Learning Modules on the Human Dimensions of Global Change
"Human Driving Forces and Their Impacts on Land Use/Land Cover"

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Project coordinator, Susan Hanson, Clark University, acknowledges the support of the National Science Foundation (NSF) to the Association of American Geographers (AAG) (Grant No. DUE-9354651) for the development of these teaching materials. Administrative support is provided through the AAG's Second Commission on College Geography (CCG2) and the AAG's Educational Affairs Director, Osa Brand, and her staff. General project support is provided by Clark University, Worcester, Massachusetts which also hosted a workshop to develop the modules further. The hard work of the conference participants evident in these materials is greatly appreciated. Kay Hartnett, Clark University, gave most generous and proficient graphic design advice. Module authors, co-authors, and other contributors are solely responsible for the opinions, findings, and conclusions stated in this module which do not necessarily reflect the views of the NSF or AAG.

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Editor's Note

A major goal of this project "Developing Active Learning Modules on the Human Dimensions of Global Change," is to disseminate instructional materials that actively engage students in problem solving, challenge them to think critically, invite students to participate in the process of scientific inquiry, and involve them in cooperative learning. The materials are appropriate for use in any introductory and intermediate undergraduate course that focuses on human-environment relationships.

We have designed this module so that instructors can adapt it to a wide range of student abilities and institutional settings. Because the module includes more student activities and more suggested readings than most instructors will have time to cover in their courses, instructors will need to select those readings and activities best suited to the local teaching conditions.

Many people in addition to the principle author have contributed to the development of this module. In addition to the project staff at Clark University, the participants in the 1995 summer workshop helped to make these materials accessible to students and faculty in a variety of settings. Their important contributions are recognized on the title page. This module is the result of a truly collaborative process, one that we hope will enable the widespread use of these materials in diverse undergraduate classrooms. We have already incorporated the feedback we have received from the instructors and students who have used this module, and we intend to continue revising and updating the materials.

I invite you to become part of this collaborative venture by sending your comments, reactions, and suggested revisions to us at Clark. To communicate with other instructors using hands-on modules, we invite you to join the Hands-on listserve we have established. We look forward to hearing from you and hope that you will enjoy using this module.

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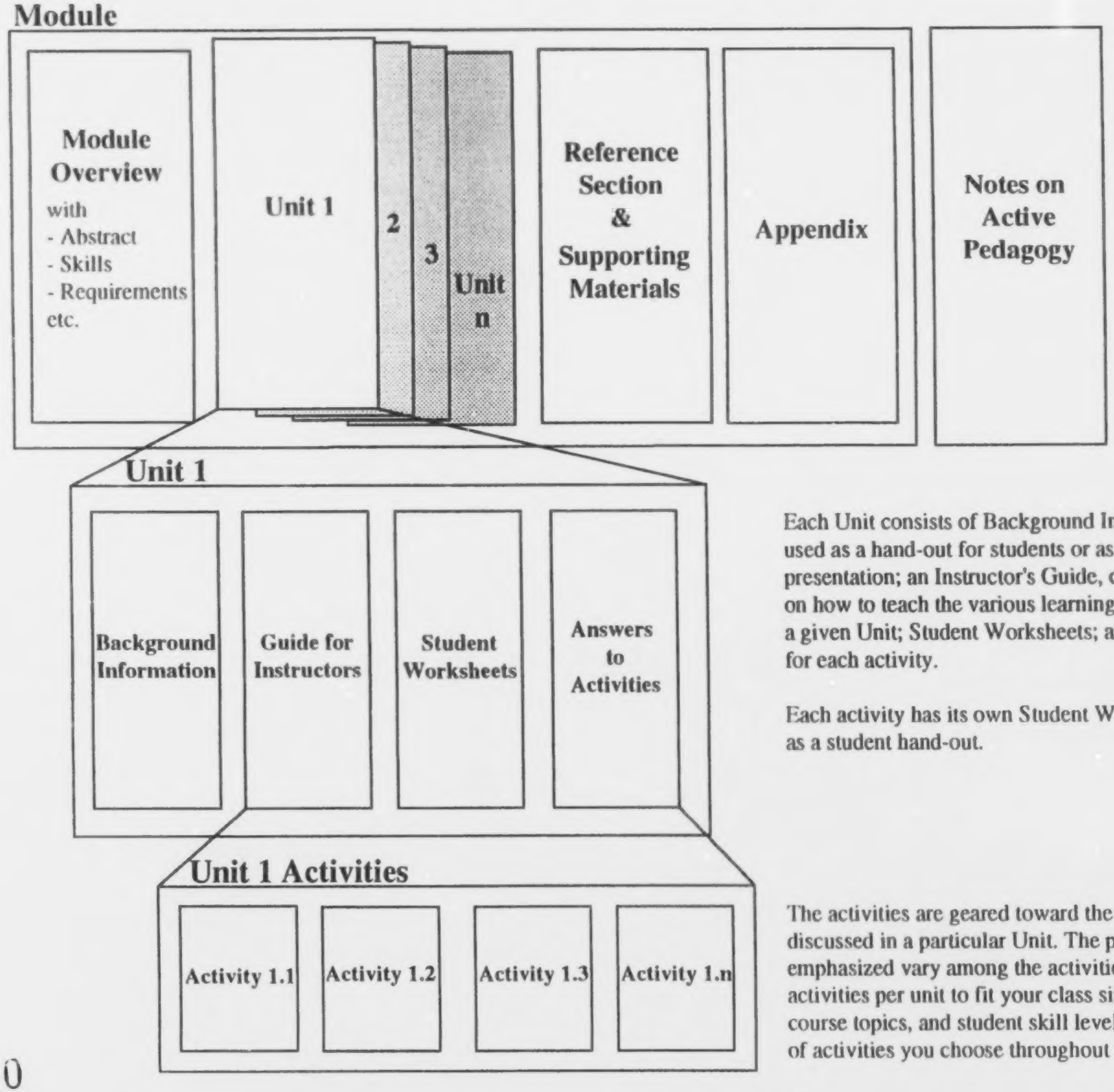
List of Acronyms

AAG	Association of American Geographers
BLM	Bureau of Land Management (United States)
CCG2	Second Commission on College Geography (within the AAG)
CEQ	Council of Environmental Quality (United States)
CIA	Central Intelligence Agency (United States)
CIESIN	Consortium for International Earth Science Information Network
ET	Earth Transformed (by Human Action) Program at Clark University
FAO	Food and Agriculture Organization (United Nations)
GCC	Global climate change
GDP	Gross domestic product
GEC	Global environmental change
HDGC	Human dimensions of global change
HDP	Human Dimensions Program
IIASA	International Institute for Applied Systems Analysis (Austria)
IGBP	International Geosphere-Biosphere Program
LULC	Land use/land cover
MAB	Man and Biosphere Program
MSS	(Landsat) Multi-spectral scanner
NCGE	National Council for Geographic Education (United States)
NOAA	National Oceanic and Atmospheric Administration (United States)
NRC	National Research Council (United States)
NTIS	National Technical Information Service (U.S. Department of Commerce)
ORNL	Oak Ridge National Laboratory (Oak Ridge, Tennessee)
OTA	Office of Technological Assessment (United States)
PRB	Population Reference Bureau
SCOPE	Scientific Committee on Problems of the Environment
SSRC	Social Science Research Council
UN	United Nations
UNECE	United Nation Economic Commission for Europe
UNEP	United Nation Environment Program
UNESCO	United Nation Educational, Scientific and Cultural Organization
US (USA)	United States (of America)
USGS	United States Geological Survey
USSR	Union of Soviet Socialist Republics
WCED	World Commission for Environment and Development (United Nations)
WRI	World Resources Institute

Guide to this Module

This guide is meant to help you navigate this module.



The module is divided into Units, i.e., sections that are thematically coherent and that could, if necessary, stand alone. In addition, the module contains a Reference Section, Supporting Materials and an Appendix. The Supporting Materials can be used to facilitate the teaching of this module or simply to augment it with interesting ideas and information. Additional sections with further information may or may not be present, e.g., a list of accronyms, or a glossary. A separate section on Active Pedagogy comes with every module purchase.

Each Unit consists of Background Information that can be used as a hand-out for students or as the basis for an in-class presentation; an Instructor's Guide, consisting of suggestions on how to teach the various learning activities associated with a given Unit; Student Worksheets; and the Answers expected for each activity.

Each activity has its own Student Worksheet that can be used as a student hand-out.

The activities are geared toward the theme(s) and concepts discussed in a particular Unit. The particular skills and themes emphasized vary among the activities. Choose one or more activities per unit to fit your class size, time, resources, overall course topics, and student skill levels. Be sure to vary the types of activities you choose throughout the module.

Summary: Human Driving Forces and their Impacts on Land Use/Land Cover

Abstract

Land use/cover change has occurred at all times in all parts of the world. Most affected and involved in these processes are the environmental spheres of water, soil, and vegetative cover, which are closely linked to geomorphology, climate, fauna, and especially human societies. The linkages among spheres are highly complex and incompletely understood. The most profound questions with respect to land use/cover and global change are:

✔**What forces drive land use/land cover change?**
✔**What impacts – direct and indirect, now and in the future – do these changes have on the environment and on human society?**
✔**How might we respond to them most effectively?**

The module introduces the student to the complexities inherent in these questions, but mainly focusses on the first of these. It illustrates the central role of the study of land use/cover change within the larger field of global environmental and climatic change, and is thus a good unit to introduce this topic.

Module Objectives

✔ **to provide an introductory qualitative overview of the interactions among driving forces, proximate sources, and environmental impacts of land use/land cover (LULC) changes**;
✔ **to problematize the collection, compilation, and assessment of quantitative data** on regional and global land use/cover change;
✔ to assess quantitatively some **general relationships between land use/cover changes and human driving forces**; and
✔ to stress the **importance of scale** in the study of human impacts on land use/cover.

Skills

This modules builds the abilities
✔ to formulate and structure a research problem;
✔ to find relevant data from various sources (library, Internet, research centers);
✔ to critically assess LULC data;
✔ to interpret and create scatterplots;
✔ to read LULC maps;
✔ to work cooperatively in group projects;
✔ to engage in group discussion;
✔ to communicate ideas orally and in writing.

Activities

The range of activities suggested for this module includes:
✔ group and panel discussions;
✔ team work;
✔ semi-formal interviewing;
✔ writing various kinds of papers (essays, reports, etc.);
✔ data searches and critical/careful assessment;
✔ reading and producing scatterplots;
✔ correlation and (optional) regression analysis; and
✔ reading maps.

Human Dimensions of Global Change Concepts

✔ Cumulative vs. systemic global change
✔ Human driving forces/macro forces
✔ Proximate sources of change

✔ Global vs. regional land use/cover changes

Geographical Concepts

✔ Land use/land cover
✔ Scale
✔ World regions

Material Requirements

✔ Student Worksheets, Supporting Materials (provided)
✔ Calculators or computer access (spreadsheet software)
✔ Land use/cover maps (atlas) (sample provided)
✔ Pencils
✔ Readings (some provided)

In-Class Time Requirements

✔ 6 class units, 50 min. each (2-3 weeks), assuming that at least 1-2 activities per unit are completed.

Difficulty

Intermediate to challenging. The module requires an ability to abstract, to work independently and in groups, and to critically analyze readings and data. While the module does not require previous knowledge of global change, it does require students to grapple with scientific texts.

Module Overview

When we think of global environmental changes, many of us think first of the large-scale deforestation of the Amazon and Southeast Asian rainforests; others may think of desertification in dry land areas of Africa or the destruction of habitats and the resulting loss of biodiversity. These are the land use and land cover changes that have received the most attention in the popular press and in the scientific literature, but land use/cover changes have occurred at all times in the past, are presently ongoing, and are likely to continue in the future in all parts of the world. Most affected and involved in these processes are the environmental spheres of water, soil, and vegetative cover, but it is misleading to think of these as isolated from the geomorphology, climate, fauna, and especially human societies. These linkages between spheres are highly complex and, as of yet, incompletely understood. The most profound questions with which scientists working on land use and global change struggle are:

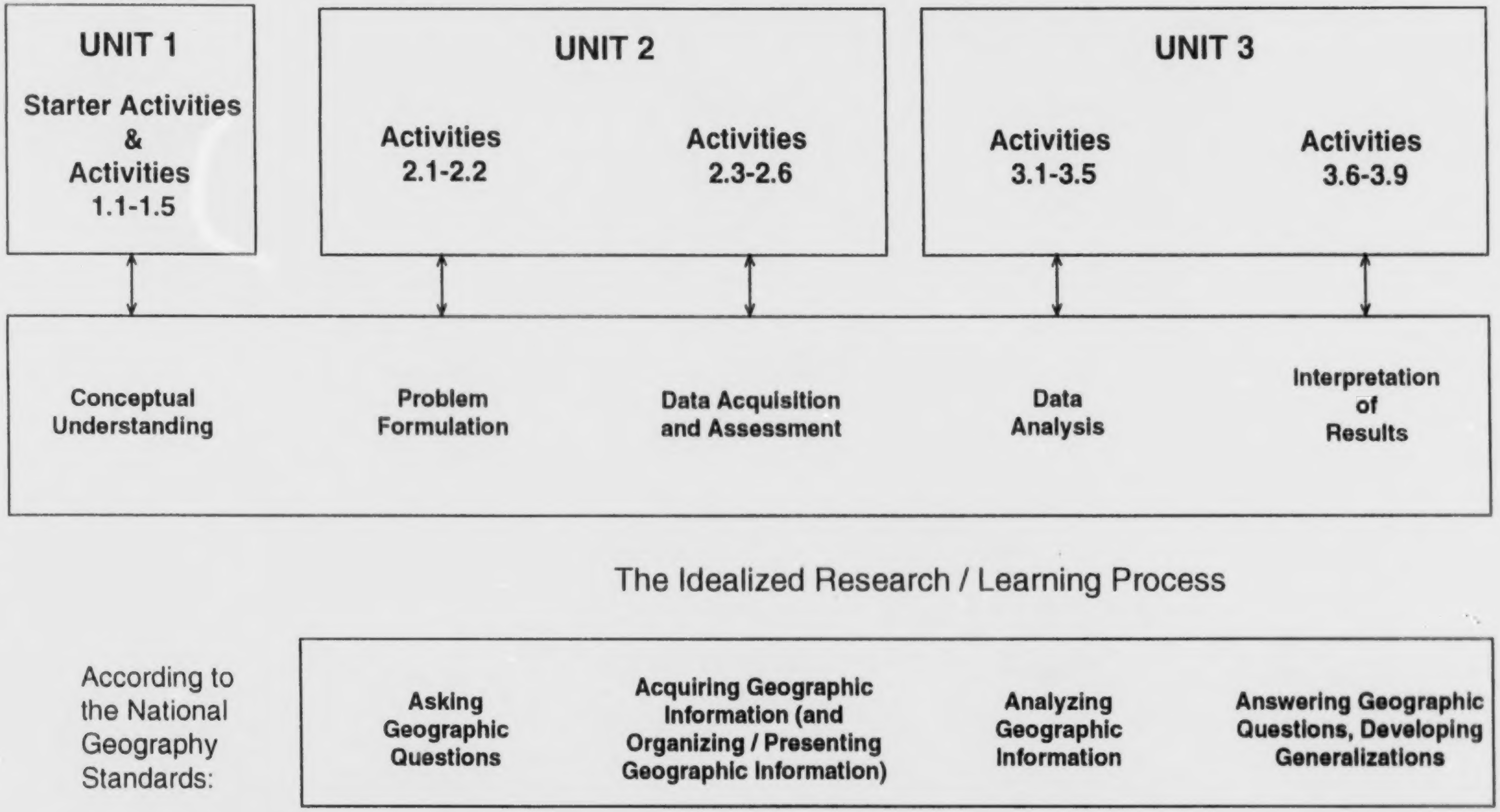
- **What forces drive land use/land cover change?**,
- **What impacts -- direct and indirect, now and in the future -- do these changes have on the environment and on human society?** and lastly,
- **How can we respond to these changes most effectively?**

This module introduces the student to the complexities inherent in these questions. Its main focus, however, is on the first of these questions. In the first unit of the module students are introduced to the human dimensions of global change, and they learn about the central role that the study of land use/land cover change plays within the larger field of global environmental and climatic change. In the second unit, students learn about selected land use/land cover areas and take a critical look at the data available for their study. In the third unit, students relate land use changes to human driving forces, and link changes at a global scale to those at a local scale, thus making global change a personal concern. The module's three main objectives are:

- **To provide an introductory qualitative overview of the interaction among driving forces, proximate sources, and environmental impacts of land use/cover changes;**
- **To problematize the collection, compilation, and assessment of quantitative data on regional and global land use/land cover change; and**
- **To assess quantitatively some general relationships between land use/land cover changes and human driving forces.**

The module introduces some of the basic concepts underlying the study of the human dimensions of global environmental change (systemic vs. cumulative global change, human driving and mitigating forces, proximate sources of change, land use and land cover); it illustrates the extreme difficulties of data collection and assessment so fundamental to the study of global processes; and it involves students in using some of the essential statistical (analytical) tools of scientific research (regression, correlation, scatterplots, etc.). Throughout, students will learn to appreciate the crucial importance of scale in global change studies in general, and in drawing inferences from the results of the statistical analysis. Thus the module teaches students about land use/cover change in the context of global change and builds a critical understanding of the research process (see Figure 1).

Figure1: Module Overview: Its Structure and Activities


UNIT 1
Starter Activities & Activities 1.1-1.5
UNIT 2
Activities 2.1-2.2
Activities 2.3-2.6
UNIT 3
Activities 3.1-3.5
Activities 3.6-3.9
Conceptual Understanding
Problem Formulation
Data Acquisition and Assessment
Data Analysis
Interpretation of Results
The Idealized Research / Learning Process
According to the National Geography Standards:
Asking Geographic Questions
Acquiring Geographic Information (and Organizing / Presenting Geographic Information)
Analyzing Geographic Information
Answering Geographic Questions, Developing Generalizations

Overview of Module Activities

The activities in this module are designed to teach some basic concepts and problems of Human Dimensions of Global Change (HDGC) research, especially those related to data acquisition, aggregation, and interpretation. In addition, students learn some fundamental learning, communication, and research techniques.

Five sets of activities grouped with the three units of this module follow a logical (if somewhat idealized) sequence that is typical of the scientific research process. In the following diagram, the numbers indicate student activities.

Unit 1: Starter Activity (SA) and Activities 1.1 through 1.6
Unit 2: Activities 2.1 through 2.6
Unit 3: Activities 3.1 through 3.9

Conceptual Understanding ⇨	Problem Formulation ⇨	Data Acquisition and Assessment ⇨	Data Analysis ⇨	Interpretation of Results
SA, 1.1-1.6	2.1-2.2	2.3-2.6	3.1-3.5	3.6-3.9
UNIT 1	UNIT 2		UNIT 3	

Activities

Each set of activities covers one *step* in this idealized sequence, with Activities 3.1-3.5 incorporating analysis and interpretation, and Activities 3.6-3.9 relating the global issues to the local and the students' personal experience. A variety of activities is offered in each unit. You should select those activities that are feasible for your class, according to class size, students' abilities, institutional facilities and resources, etc.

Organizational Note

The activities section in each unit is structured into three parts: an *Instructor's Guide*, *Student Worksheets*, and an *Answers* section (again for the instructor). For example, Unit 2 is accompanied by Activities 2.1 through 2.6. The *Instructor's Guide* for this unit outlines suggested readings, material requirements, skills taught in each activity, learning outcomes, and a detailed description of the tasks students have to complete and how to teach the suggested activities with possible alternatives and variations. The *Student Worksheets* (one per activity) are meant as hand-outs to students and provide the necessary instructions for each activity. The *Answers* section lists expected results of each activity, i.e., either specific results or points to check for in students answers.

1 Interactions Among Driving Forces, Proximate Sources, and the Impacts of Land Use/Land Cover Change

Background Information

Introduction to Global Change

Environmental spheres

The earth is constantly changing. Every environmental domain, that of water (hydrosphere), of the air (atmosphere), of rocks (lithosphere) and soils (pedosphere), of ice (cryosphere) and of vegetation and living organisms (biosphere) -- all of these domains are in constant flux. The changes that occur may happen in matters of seconds or over millions of years; they may occur in one place only, or on the entire globe; and changes in one environmental sphere affect changes in others. So the earth can be thought of as a system of interacting evolving, environmental spheres.

Earth as a system

Interplay of natural and human driving forces in environmental change

At least since the end of the last glaciation (about 12,000 years ago), we have relatively widespread archeological evidence of the presence of human beings. Since then, changes in the earth's spheres are no longer purely environmental, i.e., driven by geophysical and/or biochemical fluctuations and events. They are also the result of human actions. In most cases when we look at environmental changes it is not immediately obvious which force or interplay of forces caused the changes.

Human-induced changes in the environment have always been profound and common in almost all parts of the world, but the scope (both spatially and qualitatively) of human-driven alterations of the environment has immensely enlarged as population numbers and technological capacities increased (e.g., Mathews 1983; Turner & Butzer 1992). With mounting evidence of environmental transformations on a global scale and especially serious concerns about changes in the earth's atmosphere with yet-unknown consequences for global and regional climates, scientists have become interested in these **global environmental** and especially **global climatic changes**.

Global environmental change

Global climate change

The Human Dimensions of Global Change

Because human societies enjoy and utilize the environment for the fulfillment of their basic needs (food, clothing, shelter, etc.) and wants (luxury items, social prestige based e.g. on economic status, aesthetic pleasures, etc.), humans have (or should have) a vested interest in a healthy and productive environment. Questions that concern global change scientists include what such an environment looks like, how to keep a healthy and productive environment, what forces drive its degradation, and how to manage societal activities on a global scale such that we maintain and/or repair the earth's capacity to sustain the lives and livelihoods of all of its inhabitants. Basically, scientists attempt to understand the causes, consequences, and areas of intervention for the management of global change.

These issues concerned scientists in the early 1970s, when the environmental movement began to flourish in the Western world (e.g., Commoner 1970, 1977; Ehrlich 1968; updated and revised in 1990; Meadows *et al.* 1972). This flurry of interest in the understanding and modeling of global environmental and socio-economic futures was followed by a decade or so of relative neglect, until the early 1980s, when global change research revived. It was mostly physical scientists who dealt with these questions until, in the late 1980s and early 1990s, people recognized that recent global changes are largely human-induced, that they do and will affect human societies, and thus that they could only be understood with the input from the social sciences. Since then it has become common to speak of the ***human dimensions of global change*****, i.e., of human driving forces, mitigating forces, proximate sources, impacts, and responses to global change**.

Human dimensions of global change

Human driving forces/ macro forces

Human driving forces **or macro-forces are those fundamental societal forces that in a causal sense link humans to nature and bring about global environmental changes.** In this sense, the study of global changes through the lens of nature-society relationships is a profoundly geographical theme. Human driving forces comprise the sum of individual and group actions, but they are more manageably described as collective categories of these actions

(Turner 1989: 93). An oft-cited typology of these macro-forces is presented below; it should be noted, however, that many versions of this typology and alternatives to it exist in the social science research literature on global change.

Typology of human driving forces

Table 1:

Human Driving Forces of Global Environmental Change

1. Population Change
2. Technological Change
3. Sociocultural/Socioeconomic Organization
    - 3a. Economic Institutions/Market
    - 3b. Political Economy/Ecology/Political Institutions
4. Ideology (Beliefs/Attitudes)

Source: derived from Meyer, Turner, and Young 1990

Human mitigating forces

As many researchers have pointed out, our understanding of these global forces is limited, abstract, and qualitative at best. Each global force is highly complex and insufficiently understood; it also interacts with other macro-forces and the environment. We also have little understanding of ***human mitigating forces*****, i.e., those forces that directly or indirectly impede, alter, or counteract human driving forces**. Examples of such mitigating forces may be local, national, and international environmental regulations, market adjustments, technological innovations, informal social regulation through norms and values, etc. The distinction between driving and mitigating forces can become blurry when mitigating forces have unintended side-effects that turn them into driving forces, and vice versa. An example is the switch from coal to oil as a major raw material and source of energy in industrial economies. This shift dramatically reduced coal-burning emissions and related environmental problems, but it also opened the door to a booming petrochemical industry with all its socioeconomic blessings and environmental ills.

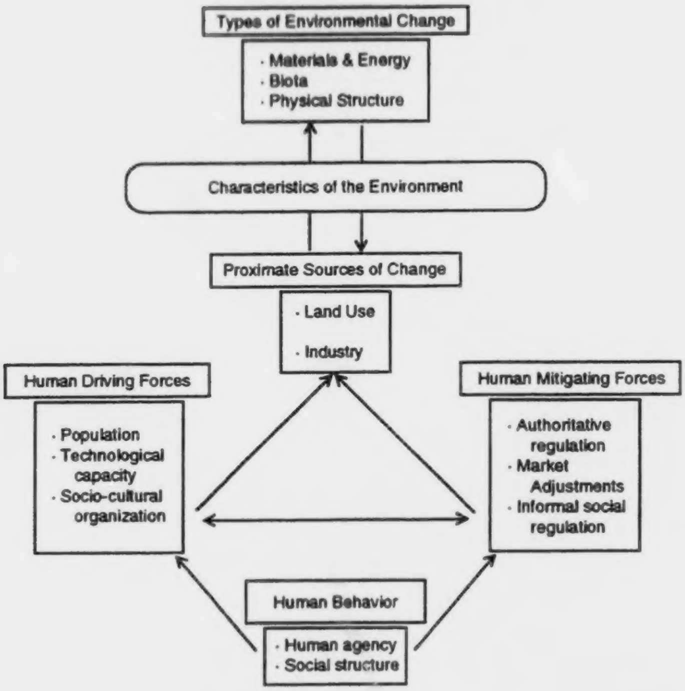
In the absence of empirical studies that might document the workings of these forces, social scientists try to extract relevant knowledge from studies undertaken for purposes other than understanding global change. Thus, our understanding of these global human driving and mitigating forces is still in the early stages. What we do know is that "the rich traditions of social-science research into [nature-society] relationships have demonstrated their great complexity and the variability that they can display by period, site, and situation. Any nature-society relationship ..., even if stimulated by a "global force," ... cannot be adequately understood independent of the contingencies of its local and historical occurrence. Prescriptions divorced from the specificities of context are not only inadequate but dangerous" (Meyer, Turner, and Young 1990: 1).

Proximate sources of change

It is therefore necessary to determine **the intermediate mechanisms that translate the multi-tiered, complex global driving forces into local human action**. In describing these mechanisms, global change researchers speak of ***proximate sources of change***. The list of such proximate sources is virtually endless, but some examples given below illustrate their role in nature-society interactions. Figure 2 below shows how human driving forces, mitigating forces and human behavior interact to bring about the proximate sources of change which in turn cause different types of land use/cover changes mediated by the characteristics of the physical environment.

Human causes of global environmental change

Figure 2: The Human Causes of Global Environmental Change



Source: Turner, B.L. 1989. *The human causes of global environmental change*. His Figure 11.1, p.91; reprinted with permission from the National Academy of Sciences.

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Causal linkages between proximate sources and environmental change

Proximate driving forces are the aggregate final activities that result from the interplay of human driving and mitigating forces to directly cause environmental transformations, either through the use of natural resources (e.g., as input into agriculture, mining activities, or as raw material for industrial production), through the use of space, through the output of waste (solid waste, emissions, pollution, etc.), or through the output of products that in themselves affect the environment (e.g., cars, plastic bags). This causality is again highly complicated when we consider issues of geographic scale, time, magnitude, and clustering of proximate sources of change:

Complications:

Geographic scale
Time lags
Perception
Thresholds
Clustering vs. single impacts

- How does geographic scale affect our understanding of these forces?
- How do we incorporate time lags between past action and current or future impacts?
- Of what magnitude does an activity have to be in order for us to recognize its causal workings?
- Where are the thresholds beyond which impacts become visible?
- How do the workings and impacts of proximate sources differ when they occur in a clustered manner rather than singly?

Types of Global Environmental Change

Types of global environmental change

These yet-unanswered questions point to another set of fundamental concepts in the study of global environmental changes. We need to define what types of environmental changes we ought to expect. Here, we present two ways of identifying environmental changes: the first (Table 2) aggregates changes in a genetic sense, i.e., by asking "how do the changes come about?"; the second (Table 3) views changes according to their occurrence, i.e., by asking "in which earth system do we find changes?". Such typologies help us detect, analyze, and understand global changes and thus ultimately to manage them.

Genetic typology of global environmental change

Table 2:
A Genetic Typology of Global Environmental Change

1. Systemic Change
2. Cumulative Change

Source: after Turner *et al.* 1990

Systemic change

The genetic typology of environmental changes hinges on the two implied meanings of the term "global". In the first *systemic* sense, "**global refers to *the spatial scale of operation or functioning of a system*.** A physical system is global in this sense if its attributes at any locale can potentially affect its attributes anywhere else or even alter the global state of the system" (Turner *et al.* 1990; italics in the original). An example of this type of change is the increase of so-called greenhouse gases in the earth's atmosphere that may lead to climate changes, sea-level changes, and other impacts. Note that globally systemic changes need not be caused by global-scale activity, only that the physical impacts of the activity need to be global in scale. The emission of greenhouse gases, like CO_2 or methane, occur **locally**, but they alter the chemical composition of the atmosphere **globally**.

Cumulative change

In the second, ***cumulative***, sense, **global refers to "the areal or substantive accumulation of localized change**. ... Changes of the cumulative type include those that 'are local in domain, but which are widely replicated and which in sum constitute change in the whole human environment'" (Turner *et al.* 1990: 17, citing H. Brookfield 1989). Examples of this type of global change include soil degradation (e.g., Blaikie 1985; Blaikie and Brookfield 1987; Grainger 1982; Tolba 1984), or the loss of biodiversity (e.g., Swanson 1995). Soil erosion or soil fertility losses resulting from local agricultural practices occur almost everywhere on earth, constituting in their totality a global change of the soils of the world. Species and habitats are lost locally, yet the phenomenon of biodiversity loss is experienced almost everywhere on earth, cumulatively causing an alteration of the biosphere.

The latter example demonstrates one difficulty with this typology: cumulative and systemic global change may not always be clearly distinguishable. We do not know with any certainty whether or not cumulative change will -- in crossing some unknown threshold -- turn into systemic global change. For example, by changing not only the number of species living on earth but also the composition of species, do we not really bring about a systemic rather than a cumulative change? The answer to this question rests on our ability to recognize global-scale impacts and our ability to trace these impacts back to biodiversity loss (see the definition of systemic change above).

Table 3:
An Occurrence-Oriented Typology of Global Environmental Change

Occurrence-oriented typology of global environmental change

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1. Changes in material and energy flows
2. Changes in biota
3. Changes in the physical structure of the biosphere

Source: after Turner 1989: 90

Material and energy flows

The second typology, more common in the physical than in the social sciences, distinguishes changes by the locales in the earth system in which they occur. Changes in material and energy flows may be geographical or temporal changes, qualitative changes (the kinds of materials or energies flowing through the earth system or its spheres), or quantitative changes (the amounts of materials or energy flowing through the system). Changes in biota have been discussed above. They include changes at the genetic, species, habitat and ecosystemic, and quantitative (amount of biomass) levels. Providing space for biotic changes as one of three fundamental types of global change points to the central role the biosphere plays in the creation and maintenance of a habitable human environment. Finally, changes in the physical structure of the biosphere refer to the structural interlinking of the earth's spheres.

Biota

Structure of the biosphere

Again, these three types of changes are highly interconnected and overlapping as were systemic and cumulative changes in the previous typology. It should be remembered as well that the focus in the study of the human dimensions of global change is the **interaction** between these types of global environmental change and humans. This interaction is highly specific to the local conditions both of the environment and of society. Human actions are grounded in place, and because the differences between places are immense, we must expect that this human-environment relationship will vary widely from place to place.

Land Use and Land Cover Change

Land use and land cover change

In the study of global change, human interactions with the environment are tackled in one of three fundamental ways: (1) the human **causes** of change, (2) the **consequences** for, or impacts of changes in the environment on, society, and (3) the societal **responses** to change. We have already seen that the ways in which humans use the earth's resources in their sociocultural, technological, economic, political, and organizational context provides the entry point to gaining a better understanding of global change.

Land use and global environmental change

The study of land use and land cover is central in this respect (see Figure 3). ***Land use is the observed immediate reason and/or manifestation of environmental change***. Consider the following examples: Agricultural and forestry practices have changed entire landscapes; land-management practices more generally alter plant and animal communities both at the species and habitat level, or they affect nutrient cycling and distribution in the soil; creation or changes of transportation routes dissect habitats, and alter water and energy flows; industrial emissions affect environmental and human health and built structures (as for example through acid deposition, or the destruction of the ozone layer). Similarly, we must be interested in how humans adjust to a variable and changing environment, which factors facilitate or impede such adjustments and adaptations, and which factors augment or diminish societal vulnerability to, say, climatic variability, and thus what might be the most effective avenues to take in response to global environmental changes.

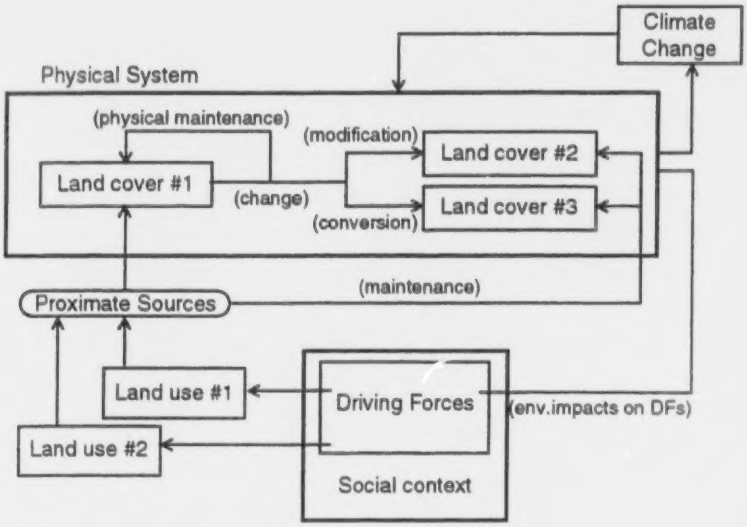
Scientists dealing with land use and land cover changes ask:

- "How are land-use changes contributing to global environmental changes?,
- "What social-economic factors determine land use, and how will they change?", and
- "How does land use modify processes that influence global change?" (Ojima, Galvin, and Turner 1994: 300).

These questions have no definitive answers as of yet; rather, they mark the frontier of current land use/land cover research. Figure 3 below shows the connections that these questions aim at: different land cover types get changed through land use activities -- resulting in proximate sources of change -- which are driven by the larger forces at work in any given social context. The physical environment, of which land cover is but one aspect, is very much influenced, and in turn influences, the changing global climate.

Figure 3: Linkages Among Human Causes, Land Use, and Land Cover

Linkages among human causes of change and land use/cover



Source: Ojima, Galvin, and Turner 1994; their Figure 1, p.301; reprinted with permission from the American Inst. of Biol. Sciences.

Land use

Land cover

Let us begin by defining and distinguishing land use and land cover. ***Land use*** **"is the way in which, and the purposes for which, human beings employ the land and its resources"** (Meyer 1995: 25). Examples include farming, mining, and lumbering. ***Land cover***, by contrast, **"describes the physical state of the land surface**: as in cropland, mountains, or forests" (Meyer 1995: 25). The term originally referred to the type of vegetation that covered the land surface, but has broadened subsequently to include human structures, such as buildings or pavement, and other aspects of the physical environment, such as soils, biodiversity, and surface and groundwater.

As Meyer correctly pointed out, changes in land use that lead to changes in land cover do not necessarily imply a degradation of the land (Meyer 1995: 25). That is, these changes do not necessarily mean a **decline in productivity or in other desired characteristics of the land**. Presumably most land use changes are motivated by the desire to improve the land for human use or pleasure (for example, in the use of fertilizers, pesticides, powerful machinery, increases of total cultivated land area to feed an increasing population, or the setting aside of primary forests in national parks for aesthetic and leisurely enjoyment only) (Ruttan 1971). Degradation -- a state profoundly determined by our perception of the environment -- may occur nevertheless. It may be unintentional and unperceived; it may result from carelessness or from unavoidable necessity if it occurs in the course of working for personal (economic) survival (Blaikie 1985; Blaikie and Brookfield 1987; Watts 1983).

Land degradation

As Figure 3 above depicted, land use/land cover and changes therein are linked to the proximate and driving forces of global change. In the activities accompanying this first unit, we will begin to examine these complex linkages and how they play out in our own local environment. Later exercises will take us to the regional and global scales and allow us to quantitatively analyze the relationships between human driving forces and land use/cover change.

1 Interactions Among Driving Forces, Proximate Sources, and the Impacts of Land Use/Land Cover Change

Instructor's Guide to Activities

Starter Activity/Questions

Starter Activities and/or questions are designed to capture the students' attention, to recall their pre-existing knowledge on a subject and give them an opportunity to use expressive language (see *Notes on Active Pedagogy*), to engage them with the subject, and/or to stimulate their thinking with provocative statements. The questions can be a good stimulus for class discussion.

- Why should I care that "they" are cutting down the rainforest? It's so far away anyway.
- Have you ever seen a clear cut area? What did it look like? What effects do you think a clear cut would have on the forest animals, on the soil, on the local climate? Did you see whether that same spot was reforested later? If it wasn't reforested, did anything grow there after a while?
- Is it not just cosmetics when we clean and prop up our neighborhoods on Earth Day?
- Imagine two farmers working their fields: one in Iowa, the other in Indonesia -- who contributes more to global environmental change? Why? Is that answer really so easy?
- What is "global warming"? Does it have anything to do with the "ozone hole"? And if you think so, what?
- What's the difference between global climate change and global environmental change? How are they linked?
- How do you imagine [fill in local (well-known) examples: your local wetland, the prairie, the old growth forest, the water reservoir, a habitat for a rare species, etc.] to change if our climate changes to [fill in regional expectations for a changed climate such as warmer and drier]?
- Imagine your city planners want to build a new highway around the city. Promoters of the new highway claim that it will do away with the daily traffic jams that frustrate hundreds of thousands of commuters every day. You are an environmental consultant who is to evaluate the proposed project from an ecological point of view. Because you are very

concerned about global change, you consider not only local but also regional to global effects of extending traffic routes for motor vehicles. Think of driving forces, proximate sources, and impacts. Make a list of all the possible consequences -- positive and negative -- you can think of and compare them with your classmates' lists.

Conceptual Understanding → Problem Formulation → Data Acquisition and Assessment → Data Analysis → Interpretation of Results

Goal

Students learn to distinguish the concepts central to this module, **land use** and **land cover**. They use the definitions provided in the *Background Information* and the assigned readings, and apply them to LULC maps available at the institution, or -- if that is not possible -- to the maps provided with this module.

Learning Outcomes

After completing the activities associated with this unit, students should:

- know the difference between land use and land cover;
- be able to read a LULC map;
- know why LULC is an important dimension in the study of the HDGC;
- have had some practice taking "good" notes on readings.

Choice of Activities

It is neither necessary nor feasible in most cases to complete all activities in a unit. Instead, select at least two or more from each unit, covering a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

1.1 Taking Good Notes	-- Generic note-taking skills
1.2 Before You Lived Here...	-- Informal interviewing
1.3 Reading Land Use and Land Cover Maps	-- Map reading and interpretation
1.4 Linking Regional Land Use/Cover and Global Change	-- Essay writing
1.5 Field Trip: The Changing Landscape	-- Field trip, landscape interpretation
1.6 Film: *"Spaceship Earth"*	-- Critical film analysis

Suggested Readings with Guiding Questions

The following readings are recommended to accompany the activities for this unit and to supplement the *Background Information*. Choose those readings most appropriate for the activities you select and those most adequate for the skill level of your students. Guiding questions help students focus while reading.

- *Background Information*, Unit 1 (provided; or else use this in a lecture with the provided overheads)
  ☐ Is global change something new in the history of the earth?
  ☐ What's the difference between changes in prehistoric times and now?
  ☐ What types of global environmental changes are there?
  ☐ What does land use/cover change have to do with global environmental change?
- Ojima, D.S., K.A. Galvin, and B.L. Turner II. 1994. The global impact of land use change. *BioScience* 44, 5: 300-304.
  A short scientific paper that repeats part of the *Background Information*. Better to read after basic concepts have been explained through an in-class discussion or the *Background Information*.
  ☐ How is global land use and land cover change related to other global environmental changes?
  ☐ How are they related to the macro forces and the proximate sources of change?
  ☐ How certain is our scientific knowledge about these interrelated issues?
- Meyer, William B. 1995. Past and present land use and land cover in the USA. *Consequences* 1, 1: 24-33.
  An easy read, also picking up parts of the *Background Information*, but specific to the United States.
  ☐ What is land use? What is land cover? Examples for each?
  ☐ How has the land use and land cover changed in the US?
  ☐ Are humans merely destructive to their environment? Why or why not?
- Heilig, Gerhard K. 1995. Neglected dimensions of global land-use change: Reflections and data. IIASA Reprint from *Population and Development Review* 20, 4: 831-859.
  This is a more critical paper, complementary rather than essential, but a nice introduction to some of the exercises that students will do in the beginning.
  ☐ What are the acknowledged and what the neglected dimensions of global change according to the author?
  ☐ Write down some examples of these neglected dimensions and what their connection is to land use change!
- Other introductory readings related to the basic concepts of HDGC (at instructor's discretion; see also section *Additional Readings* under *Supporting Materials*).

Activity 1.1 Taking Good Notes

Goal

The activity is meant to teach the generic skill of good note-taking from a reading. Students should become accustomed to taking notes on almost everything they read for the class as it helps them structure, understand, and recall more readily the information contained in a text.

Skills

✓ note-taking
✓ text comprehension

Material Requirements

Student Worksheet 1.1 (provided)
Supporting Material 1.1 "Taking notes that make sense -- even in a year from now ..." (provided)
Suggested or alternative readings listed for Activity 1 (some provided)

Time Requirements

Variable (depending on length of chosen readings and students' skill levels)

Task

Students learn with the help of guiding questions (see *Suggested Readings* above) and the help of their instructor, how to take good notes on their readings, i.e., they learn to discern the structure of a text, and subsequently to structure their own notes, to paraphrase the main argument(s), and to distinguish "important" information from "text fillers."

A hand-out on note-taking is provided (*Supporting Material 1.1*). Make this a "standard" exercise that students learn to do automatically as they read assigned class material.

The time required varies with the length of the readings and students' reading skills and ease with the material. Instructors should choose readings accordingly.

Activity 1.2 Before You Lived Here ...

Goal

Students learn to distinguish two basic concepts -- land use and land cover -- and apply them by examining through a variety of sources the local land use/cover history.

Skills

✔ relating general HDGC and LULC concepts to students' specific local situation
✔ informal interviewing
✔ data searching
✔ oral reporting

Material Requirements

Student Worksheet 1.2 (provided)
(Possibly access to old local maps, archival information, development plans, etc.)

Time Requirements

Preparation outside of class: 1-2 days
In-class reports: >15 minutes

Task

Students learn to distinguish between land use and land cover by looking at an example very close to home. Ask them to find out about the land use and land cover history of the general area or even just the lot on which the building they currently live in or their parents' house is built. They should seek as much information as possible, going back in time as far as possible, using old maps, archival information, old development plans, but also oral information from their parents and grandparents if possible, old photographs, even drawings or paintings if such exist.

Sources for such material range from family photo albums, to libraries and map libraries, to historical societies' archives, and town planning offices. The results of their findings could be presented in a number of creative ways, depending on skills, interests, and time given to this activity. Students might give an oral report, design a poster, or write a short (maximum of 3 pages) summary including maps or pictures, and quantitative information if available.

Make sure students clearly distinguish land uses and land covers. You might also challenge them to infer land cover (at least roughly) from a known land use. The exercise is a take-home exercise (that could be adjusted as a task for pairs of students), but in-class report of findings and/or debriefing may take at least 10-15 minutes.

Activity 1.3 Reading Land Use and Land Cover Maps

Goal

Students learn to distinguish land cover from land use by reading maps, i.e., they must understand the difference in meaning between these concepts and apply them correctly to the concrete examples shown on a land use/cover map using the map legend. Assuming a change in the land uses/covers they detect, students then learn to determine when an environmental change becomes global, and what type of change (using the introduced typologies from the *Background Information*) it constitutes.

Skills

- ✔ map reading
- ✔ application of general definition of LULC concepts to concrete map examples
- ✔ inversely, abstraction from concrete examples to general LULC concepts

Material Requirements

Access to LULC map sheets or atlases in sufficient numbers for the class
(see e.g., the Map Supplement *Seasonal land-cover regions of the United States* in the *Annals* of the Association of American Geographers 85, 2, with text, ibid., 339-335 [text provided])
Alternatively, for very big classes, instructors may copy a legible land cover or land use map in sufficient numbers or use *Supporting Material 1.3* (provided)
Student Worksheet 1.3 (provided)

Time Requirements

10-20 minutes in class

Tasks

Students or instructors choose a region in an atlas or on a provided thematic map sheet (e.g., vegetation cover, land uses like agriculture or forestry, etc.) and learn to read the map using the legend. This may well be [if available] a map of their locale or region, or a region that is thematically central to the remainder of the course. Students determine which of the categories depict land use, which land cover. The basic alternatives here are that students either list land uses and land covers in these categories, or that they determine which of two maps shows land use and which land cover. This requires students' understanding and recall of the land use and land cover definitions provided in the *Background Information* or on the overheads (originals for overheads provided in the *Supporting Materials* section).

Then ask students to assume changes in these land uses and land covers and ask them to determine whether such change would constitute systemic or cumulative global change. When would this change become global in scope? Why would it be the type of global change they believe it is? Would it be a change in material flows, energy flows, the physical structure of the environment, or in the biota? Students must apply the two types of classification of global changes introduced in the first unit.

Many maps are suitable for this activity. Most basic atlases of the world, the US, or any other country contain thematic maps on natural vegetation cover, land forms, or certain aspects of the environment (all types of land cover) and land use. Because these maps are usually in color, they are more difficult and expensive to reproduce for this activity. The same is true for USGS map sheets (topographic or thematic), or CIA country maps that usually have small inserts of land use and land cover maps; but if those are accessible to your class, they constitute a rich and copyright-free resource. Also suitable are monographs that treat land use or land cover of any given country and geography textbooks. Both may contain color or black and white maps that could be used here, the latter of which would be more easily reproduced. If map resources are scarce and/or copyright restrictions too great an obstacle, students could use the provided maps of Brazil (*Supporting Material 1.3*).

This activity is designed as an in-class exercise, and requires 10-20 minutes depending on students' map reading skills.

Activity 1.4 Linking Regional Land Use/Cover and Global Change

Goal

Students relate local to regional land use/cover changes to global human driving forces and understand the importance of land use/cover change in the context of global change research.

Skills

✔ interpreting LULC information (whatever is found, provided or known about the region)
✔ text comprehension
✔ relational thinking
✔ essay (letter, report) writing
(✔ alternatively, group discussion [arguing, leading, note-taking, process evaluating])

Material Requirements

Access to information on land use and land cover of the region (could include maps, remote sensing imagery or areal photography if feasible; also written descriptions and students' personal knowledge).

Student Worksheet 1.4 (provided)

Time Requirements

Preparation outside of class 1-2 days
(In-class discussion 25 minutes)

Task

Students write a short essay, describing the land use and land cover of a region of their choice (or continuing with the region studied in Activity 1.3), speculating (with, at a minimum, the *Background Information* provided in Unit 1) how these regional land uses and land covers are connected to global environmental change. For example, what does deforestation of old growth forest have to do with global change? What are the causes, the macro/driving forces and the proximate sources of change? Instead of an essay, you may choose to assign a different text genre, e.g., ask students to write about global LULC change and human driving forces in the form of a letter to a friend, a newspaper article, or a travel report that will appear in a glossy magazine.

Students should use appropriate caution in making causal connections. Mainly, their essay/ writing should explain why LULC is important in the study of the HDGC. Encourage students to rely on some of the readings suggested for Activity 1. (See also *Notes on Active Pedagogy* for suggestions on writing essays.)

Alternatively, if your class is too large for even short essay writing to be feasible, the same issues can be discussed in small groups in class. In that case, assign individual students in each group to the roles of discussion leader, reporter (taking notes on the main arguments), and process observer (making sure that everyone gets involved and has a chance to speak). The instructor functions as an external observer, facilitating light-handedly if necessary, and encouraging students to think creatively and to look for agreement on specific linkages between the regional situation and global change.

Overall, look for the creative use of local or regional, pertinent examples. Before you assign this task, make your expectations clear to them. Stress what you are looking for, perhaps giving one clarifying example of a "linkage."

Activity 1.5 Field Trip: The Changing Landscape

Goal

Students engage in the art of observation and then interpretation of the mosaic of physical and human structures that make up the landscape. They see how "real" human activities bring about land use/cover patterns.

Skills

✔ application of abstract understanding of LULC concepts to "the real world"
✔ taking field notes
✔ landscape observation and interpretation

Material Requirements

Transportation to field site(s)
Note pad and pen

Time Requirements

1 half day

Task

This is an optional activity, and one that may be undertaken in connection with a field trip for other purposes. Field trips have the great benefit of making abstract concepts and relationships very "real" because students connect classroom knowledge with examples of things familiar.

Point out to students with a few examples, and then have them distinguish land uses and land covers in the landscape. If students completed Activity 1.2, you may refer to historical land use and land cover once in place where they now see a modern human landscape. It is quite possible to see signs of historical land uses side by side with those of modern ones.

Students should take field notes and either write a one page field trip report, or include what they saw in other exercises in this or later activities of this module.

Activity 1.6 Film: *"Spaceship Earth"*

Goal

The film is meant to capture students' attention for the subject matter of geography and global change in general. It can be used by the instructor as a way to assess students' knowledge of these matters at the beginning of this unit/module.

Skills

✔ film comprehension
✔ interpretation of information
✔ critical discussion of movie

Material Requirements

A copy of the educational video series "Spaceship Earth"

Ten units of 30 minutes each, two episodes per video cassette; written by Nigel Cader. The series explores global geography using satellite remote sensing, computerized mapping, live film footage, and animation. The themes of the series focus on issues of ecology, economics, and pollution, and are thus well suited as a lead into the linkages between geography and global changes. The titles of the ten units are:

☐ Cassette 1 (Parts 101 and 102): The new global geography -- Living quarters
☐ Cassette 2 (Parts 103 and 104): Restless rock -- A global market
☐ Cassette 3 (Parts 105 and 106): The air conditioning -- The swirling sea
☐ Cassette 4 (Parts 107 and 108): Running water -- The disappearing forest
☐ Cassette 5 (Parts 109 and 110): Feast or famine? -- The watchkeepers

Note: This film, co-produced in 1991 by Teleac and Holland and Paravision for South Carolina ETV can be obtained either from the producers directly or through interlibrary loan just for the class session in which you plan to show the film. Allow sufficient time to acquire a copy of the film.

Time Requirements

30 minutes of viewing time per section
10 minutes of follow-up discussion

Task

Chose any section of this educational series to introduce students to the general subject area. Ask them to take notes of what they think is remarkable, memorable, interesting, disturbing about it. Use these comments as a basis for an in-class reflection on and discussion of the movie, and as a lead-in into the readings and other activities associated with this unit. Don't let the discussion get too long (a maximum of 10 minutes) or even drag (see *Notes on Active Pedagogy*).

An alternative to the discussion may be to ask students to imagine, speak, or write a reaction paper to some of the conditions or dilemmas and difficult problems presented in the film.

1 Interactions Among Driving Forces, Proximate Sources, and the Impacts of Land Use/Land Cover Change

Student Worksheet 1.1

Activity 1.1 Taking Good Notes

As you work through the reading assignments for this course, do not just read the articles, or just underline important passages. For understanding and remembering the arguments, it is even more important to take notes on what you read. The primary purpose of taking notes is to produce a brief overview of a text to help your memory recall the larger story of which the notes speak.

Refer to the hand-out provided by your instructor on how to take good notes so you can follow and better understand the six steps of note taking listed below!

Steps in taking notes on your readings:

1. **Gather the most obvious clues!**
2. **Put your mind's antennas out!**
3. **Read the text (again)!**
4. **Note the main argument!**
5. **Concisely list the supporting arguments under each heading (or subtitle)!**
6. **Check whether it makes sense!**

Student Worksheet 1.2

Activity 1.2 Before You Lived Here ...

Find out from your parents or grandparents when the house or apartment building in which you grew up was built. Or -- if you're far from home and find it difficult to acquire this information -- find out from your landlord when the building in which you live was constructed. (If you live in a dormitory, the college is your landlord.) Then find out how the land was used before the house or apartment building was constructed. What was the land cover then and what was it before that? You might also want to consult some older maps or check in archives if the house/apartment building is very old; your parents or grandparents might have photo albums, or the town planning office or the city's historical society might have additional interesting information.

Find as much as you can, trying to go back as far as possible (note that the variety of resources you use will in part determine your grade for this assignment), and then present your findings either orally in class or create a nice poster with graphics, maps, pictures and text -- whatever you found.

Student Worksheet 1.3 Name:

Activity 1.3 Reading Land Use and Land Cover Maps

Using the maps provided by your instructor, list the most important land uses and land covers. You may want to refer back to the definitions of these terms that you either heard in class or found in the readings. If you have doubts, ask your neighbor for help.

Land Use	**Land Cover**

Alternatively, or in addition, look at the maps of Brazil provided by your instructor. Given the legend captions on each, which of the two is the land cover, and which the land use map? Refer to the definitions of land use and land cover if you have doubts.

Now assume that the land uses and covers shown on your map change (e.g., through a change in farmer's preferences what to grow, deforestation, urban spread and so on). Discuss the following questions with your neighbor and then report to the class:

- When does environmental change become global?
- Pick two or three land uses/covers. If they changed sufficiently, would this constitute a cumulative or a systemic global change?
- Would it cause a change in material flows, energy flows, the structure of the environment, or in the biota? (Recall the typologies introduced in the *Background Information.*)

Student Worksheet 1.4

Activity 1.4 Linking Regional Land Use/Cover and Global Change

In this activity you are to relate local to regional land use/cover changes to global human driving forces and understand the importance of land use/cover change in the context of global change research.

Write a short essay, describing the land use and land cover of a region of your choice (or continuing with the region you studied in Activity 1.3), in which you speculate (using the *Background Information* of Unit 1) how these regional land uses and land covers are connected to global environmental change. For example, what does deforestation of old growth forest have to do with global change? What are the causes, the macro/driving forces and the proximate sources of change? You should use information from text books, internet databases, maps and atlases, and other sources; just make sure to cite them appropriately.

Your instructor may allow you to write in a different genre than an essay. You may, for example, write about global LULC change and human driving forces in the form of a letter to a friend or family member, or you may decide to describe what you find in a particular region as if you wrote a travel report for a glossy magazine.

Be careful in making causal connections because they are often more complex than you might think at first glance. The main point for you to show, using your regional example, is **why LULC is important in the study of the HDGC**. Rely on some of the readings suggested by your instructor and use local or regional examples pertinent to the point you want to make.

Alternatively, the same issues can be discussed in small groups in class. In that case, you will get together in small groups of three or four and take on one of the following roles: discussion leader, reporter (taking notes on the main arguments), and process observer (making sure that everyone gets involved and has a chance to speak). Your instructor will be an external observer, facilitating your discussions if necessary.

1 Interactions Among Driving Forces, Proximate Sources, and the Impacts of Land Use/Land Cover Change

Answers to Activities

Activity 1.1 Taking Good Notes

Encourage students to make note-taking a habit. Explain to them how it aids general comprehension, memory, and their degree of preparedness for classes and exams.

If students are new to note-taking on readings (or lectures) you may want to invest some time early on to practice this skill with them. It will pay off over the course of the class and students' entire college career. You may ask them to hand in their notes and return them with comments on what students did well, what they need to improve on, what they missed, what may have been too detailed. It is especially important to help them to discern and paraphrase the main argument of the paper, get a sense for where the author is coming from, and find some short phrase or clue by which students will be able to remember the paper and what it was about.

Activity 1.2 Before You Lived Here ...

Be sure that students grasp the fundamental difference between the two basic concepts:

Land Use -- is the way in which, and the purpose for which, human beings employ the land and its resources (after Meyer 1995).

Three examples:
☐ Pasture
☐ Roads
☐ Vineyards

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Land Cover -- describes the physical state of the land surface (after Meyer 1995).

Three examples:
☐ Deciduous forest
☐ Rivers
☐ Pavement

Assess students by the effort and variety of resources they use to find out about the land use history of their local area.

Activity 1.3 Reading Land Use/Land Cover Maps

The specific results of this exercise depend entirely on the maps available at your institution. In student responses look for their ability to distinguish land cover from land use. If you use the Brazil maps, the one on the left is the land use map, the one on the right is the land cover map. Go from group to group and discuss with them items that are questionable. Questions like **"What does the land look like?"** or **"What is it used for?"** might help them to find the answers to the questions they have themselves. Encourage group discussion and cooperation (see *Notes on Active Pedagogy* for hints to encourage cooperative learning).

During the testing phase, some students found little challenge in the Brazil maps. If your students feel the same way, you could use the Brazil maps simply in preparation for more the more complex maps that you find among your resources.

Be flexible in accepting answers to the first version of this activity. The main point is that students distinguish the two concepts clearly.

In response to the question "when does an environmental change become global?," students should mention the magnitude or scale of causes, impacts, and required responses to environmental change. Students should also recall the definitions of systemic and cumulative change which imply different causes and venues of global change. It may be helpful to ask students to name an environmental change that is not global, e.g., drilling an oil well, or building a seawall.

Activity 1.4 Linking Regional Land Use/Cover and Global Change

The emphasis here is on the term "linking." One of the main goals of this exercise, and of Active Learning Modules on the HDGC in general, is that students are able to **cognitively connect between local (i.e., their own) and regional activities and global-scale environmental changes, and vice versa.**

Conceptually, they should refer in their answers to
* the human driving forces (or macro forces),
* the proximate sources of change,
* the types of global changes to be expected, and
* in particular, the two graphs linking these concepts, one general, the other specific to LULC change,
(all contained in the *Background Information*, Unit 1).

Activity 1.5 Field Trip: The Changing Landscape

Field trips can fill abstract terms with meaning and relevance. We recommended that you fit a field trip into the course at some point, if at all possible.

Check students' field notes for their understanding of the major sites you visited and the concepts you explained there.

Activity 1.6 Film: "*Spaceship Earth*"

A film might be used in place of, or in addition to, the field trip to get students **engaged with the subject matter**. Follow your intuition to determine what kind of film your class might respond to most positively (the film must not necessarily be educational in its primary intent; it could simply be a film that gets students interested in global change, as via films on the potential or actual impacts of deforestation, desertification, climate change, etc.).

2

Land Use/Cover Data[1] --

Background Information

Introduction

Land use/land cover data

An essential element of the global land use/cover change agenda is the consideration of global aggregate and comparative regional conditions and relationships. This focus requires accurate global data sets that are comparable through time and across space.

Data problems

Unfortunately, most land use/cover data are not standardized and are suspect in terms of accuracy, creating rather large margins of potential error. Moreover, these characteristics are heightened for all data sets previous to 1960 and for most of the "human activities" data, regardless of the time frame.

This unit is derived from an initial assessment of global data for the study of land use/cover change, emphasizing only a limited set of LULC changes, the sources that generate them, the manner in which they are generated, and their accuracy (Young *et al.* 1990). Such a critical data assessments must precedes a meaningful examination of the relationships among various causes of change and the actual land use/cover changes.

The types of land use/cover examined here are cultivation, forest conversion (i.e., deforestation and use of once-forested land for other purposes), livestock, settlement, wetlands, and surface water. These six priority land use/covers were identified by the working group on Human Interactions, Committee on Global Change, National Research Council (NRC), and the working group on Land-Use Change, Committee for Research on Global Environmental Change, Social Science Research Council (SSRC). The latter committee identified the first three as the highest priority with the next three being of second priority. These committees also identified the problems of data as a major hindrance to documenting the spatial extent and rates of change in these covers and uses of the land and assessing the causes of this change. In the following sections, we offer a trial assessment of the data sets for each land use/cover that portend to be "global" in scale. (The discussion of all the land use/cover types and their associated data problems is rather lengthy. We therefore recommend that you split into six groups with each group focussing on just one land use type and then reporting back to the class with a summary of the information contained in each section.)

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[1] Units 2 and 3 are revised, amended, and updated versions of Young, S. *et al.* 1990. *Appendix: Global land use/cover: Assessment of data sources and some general relationships*. Report to the Land-Use Working Group, Committee for Research on Global Environmental Change, SSRC.

In Unit 3 later on, we offer a cursory quantitative assessment of the relationships among certain human "macro-forces" of land use change and the first three priority land changes. These primary or global-scale forces of global environmental change include: population change, technological change, economic development, institutions, and attitudes/beliefs (Turner *et al.* 1990). We examine only the first three forces (or surrogates of them) to provide examples of the kinds of relationships found and the problems with them.

Cultivation

Cultivation

Importance of cultivation

Importance: In order to put the data assessment below in the accurate light, we should recall why we are interested in cultivation land use/cover data in the first place. In Unit 1, we introduced the linkages between human driving forces, proximate sources of change, land use/cover, and the responses to regional and global changes (see Figure 3 in Unit 1). As stated there, we are generally interested in three questions: how land use/cover changes contribute to global environmental change, how global change will affect land use/cover, and what socio-economic and other factors co-determine land use/cover change. All of these questions will help us assess how the world's societies will be able to respond to global changes.

Linkage to global nutrient cycles

With regard to cultivation, we need to recognize that every form of cultivation is essentially linked with global nutrient cycles, i.e., the take-up, processing, temporary storage, and release of nutrients. The most important nutritional elements with regard to climate change are carbon (C), nitrogen (N), and less so, sulphur (S) -- each one occurring in a variety of molecular forms. For example, paddy rice cultivation releases significant amounts of methane (CH_4) -- a greenhouse gas contributing to global climate change -- into the atmosphere. Whether or not paddy rice cultivation is expanding, and by how much, is therefore important to know. Similarly, we want to know whether the production of food crops like wheat, rye, rice, soy, sorghum, and corn can be maintained or increased under changing global environmental conditions. Given the uneven food security situation across the globe and the fast-growing populations in most developing countries, questions about the potential for continued and even intensified cultivation are crucial. To begin even to discuss these questions we need good cultivation data.

Cropland definition

Arable land

Definition: Cultivation refers to the land use for the production of domesticated plants. **Cropland** is a collective term for land in cultivation. Croplands are commonly divided into two categories: **arable land and land under permanent crops**. The meanings of these terms vary from one data source to another. The U.N. Food and Agriculture Organization's (FAO) definition of **arable land** includes lands under temporary (annual) crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, lands under market and kitchen gardens (including the cultivation of grass), and land temporarily fallow or lying idle (FAO 1989a). The U.S. Central Intelligence Agency (CIA) also designates as arable land those area which are cultivated for crops that are replanted after each harvest (e.g., wheat, rice) (CIA 1990).

Land under permanent crops

FAO and CIA definitions for **land under permanent crops** coincide: land under crops that do not need to be replanted after each harvest such as cocoa, coffee, and rubber; it includes land under shrub, fruit trees, nut trees, and vines, but excludes land under trees grown for wood-fuel, timber, and wood by-products.

A problem with most typologies of this sort is that a land use of cultivation may also be counted as a land use of livestock production. For example, temporary meadows and croplands during fallow period, used for rearing of livestock, could be reported by some countries as pasture land, as well (see section on livestock). Also there is no definition of land under slash-and-burn agriculture within the arable land category.

Cropland data sources

Sources: Data sources for currently cultivated lands are diverse; although not numerous, they do provide uniform coverage of the world. Undoubtedly, the *FAO Production Yearbook* is the primary source for many analyses and other data outlets, such as the *UNEP Environmental Data Report* and *World Resources.* The FAO data are supplied annually by national governments and therefore lack control for uniformity and accuracy. For incomplete data, which is common for developing countries, the FAO provides unofficial or estimated numbers for land use.

At least the last ten editions of the *FAO Production Yearbook* contain information about land use dynamics for every country by providing current data and 20 years back-data (in hectares). Additionally, the *UNEP Environmental Data Report (1987-1989)* gives the same information in percentages of land area. Some regional studies (e.g., Hart 1984; Honrad 1987; Whitby and Ollernshaw 1988) contain data for ten years (for Europe), 20 years (for Central America) and 50 years (for the United States).

Other sources include the CIA *World Factbook* which provides data on the percentage of arable land and land under permanent crops by countries. Although FAO and CIA data may have been collected in different ways, the results are similar. An untapped potential source of information is various world maps depicting land

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use and cover. For example, the *Map of the Main Land Use Units of the World (1: 15,000,000)*, compiled by Soviet geographers (from Moscow State University and the Institute of Geography, Moscow) in 1987 is based on systematic analysis of numerous statistical and cartographical sources and space images -- but not on FAO data. Digitizing these maps might well provide interesting quantitative comparisons for FAO figures, although other attempts to do so have led to questions about the temporal congruence of the data (David Skole, personal communication). Such maps may well prove useful in outlining general changes decade by decade, but they are too general for more specific needs.

Cropland estimates

Estimates: Total area of land under cultivation is about 11% of world land area (1,447,509,000 ha), with 10% in arable land and 0.78% under permanent crops. The distribution of croplands varies greatly from one region or country to another. The majority of the world's cropland is concentrated in Asia (about 30%), North and Central America (about 18%), and the area of the former USSR (about 16%). Nevertheless, if we consider cropland as a percentage of total land area, Europe is the most "cultivated" region of the world, followed by Asia and North America.

The constant growth of cropland area, though already slowed from the beginning of the 1970's (only 2.7% between 1975-77 and 1985-87), has -- at least for now -- been interrupted. The world cropland area in 1993 was 0.4% less than that in 1988 (FAO 1994). The highest rate of expansion was observed in South America and Oceania (12-13%), the lowest ones in North America (1.8%) and Africa (4%). Meanwhile, Europe has experienced a decline of total area cultivated on average by 0.4% per year because of afforestation, expansion of urban areas, and abandonment of marginal lands in favor of intensifying cultivation on more productive farmland.

Cropland availability is another important measure because the level of current use influences trends in land use for the future. The total area of potentially cultivable land is 24% of the ice-free surface of the earth, and its distribution among regions is uneven: 23% of it is in Africa, 21% in South America, 20% in Asia, 15% in North America, 11% in the area of the former USSR, 5% in Australia, and 5% in Europe (Revelle 1984).

About 46% of the potentially cultivable area of the world (i.e., the land mass of the earth on which climate conditions permit cultivation) is cultivated, but there are contrasts among regions in the degree of use of their agricultural land potential. As of 1987, Africa cultivated only 23.5% of its potential cropland, although including fallow land increases this proportion considerably. According to the statistics, Southwest Asia cultivates an area larger than its potentially cultivable area, raising serious questions about the measure of arable land! Southeast Asia is also approaching the limits of its suitable land. South America uses the smallest proportion of its potential of any region, only 17.3% in 1987 (FAO 1984a).

Cropland data quality

Data Quality: Assessing the data quality for cropland is difficult, because the primary source, the FAO, does not provide controls for uniformity or measure. In addition, contradictions exist in FAO reports. For example, data from *FAO Production Yearbook Data, Computer Tape* (cited in Urban and Volltran, 1984) for the years 1961-65, 1970, 1975, 1980 differs from *FAO Production Yearbook*, vol.40 (1986) data for the same years. Data reported by governments and/or FAO estimations are corrected over time. It seems reasonable, therefore, to rely more on the most recent publications of FAO.

Problems also arise from the broad FAO definition of arable land and from the multiple use of some types of land cover during the year or over a period of years. As mentioned above, temporary meadows and land temporarily fallow can be used for livestock raising and therefore might be reported as pasture land. Also, it is difficult to figure out the area of "net arable land" or the land that was tilled in a certain year because the areas of the land lying fallow are counted within arable land and are not reported separately.

Forests

Forests

Importance: Like cropland, forests make up a land use/cover type that is functionally linked into the triplet of causes, impacts, and responses to global environmental change. How much does deforestation contribute to global climate change either through the release of greenhouse gases (foremost carbon dioxide [CO_2] and nitrous oxides [NO_x]), or through the loss of forest that could take up gases as it grows (a so-called CO_2-sink)? What drives deforestation in different socio-economic contexts? How will the productivity (growth rate) of forests change as climate changes (higher temperatures, changed moisture conditions, possibly increased stress from insects, etc.)? How much would reforestation slow the build-up of greenhouse gases in the atmosphere?

Importance of forests

All of these questions indicate the many linkages between this land use/cover type with the global environment, including the socio-economic environment. Whether you want to include this important land cover type in global models, or whether you want to predict forest changes in just one region, good forest data are crucial.

Definition: Definitions of forest vary with data sources and publications. The FAO defines forest and woodland in the *Production Yearbook* as "land under natural or planted stands of trees, whether productive or not, and includes land from which forests have been cleared but that will be reforested in the foreseeable future" (FAO 1988a: 3). The FAO cautions users of the *Production Yearbook* that "it should be borne in mind that definitions used by reporting countries vary considerably **and items classified under the same category often relate to greatly differing kinds of land**" (FAO 1988a [emphasis added]). The *1980 Tropical Forest Assessment*, a joint publication of the FAO and the United Nations Environmental Program (UNEP), does not include planted stands of trees in calculations of open and closed forest. While definitions of open and closed forest vary by source, they generally refer to the extent of tree cover over the ground or percentage of area covered by tree crowns.

Forest definition

Sources: Most of the professional users (e.g., Allen and Barnes 1985; Brown 1974, 1989; Williams 1989) cite the FAO and the World Resources Institute (WRI) as the major sources for world forest data. The FAO has included forest and woodland data in its annual *Production Yearbook* since 1950. The *Yearbook* reports data

Forest data sources

as provided by individual countries through annual questionnaires and national agricultural censuses. Unofficial data and estimates are used when necessary. Data are not available for all countries.

In association with UNEP, the FAO also published the *1980 Tropical Forest Assessment* in 1982. This assessment, covering 76 countries, was the first for global tropical forests. This information has been expanded to cover 129 developing countries and is revised annually (WRI 1990). Sources of data include: national forestry institutes; land use and survey institutions; photographic surveys (all or parts of five countries); side-looking airborne radar (all or parts of four additional countries); and satellite imagery (all or parts of 19 countries). The FAO adjusts the data to fit its definitions.

The U.N. Economic Commission for Europe (UNECE), in conjunction with the FAO, published *The Forest Resources of the ECE Region* (which includes Europe, the former USSR, and North America) in 1985 (FAO/UNECE 1985). Data were obtained through questionnaires completed by individual countries, official estimates, and FAO reports. The report presents general forest resource inventory data along with volume and mass of trees and other woody biomass.

The World Resources Institute compiles data from the FAO, the UNECE, and more recent country reports into its annual report. Tables in that report show the extent of forest and woodland, average annual deforestation rates, and average annual reforestation for the 1980s (WRI 1990). Eight countries have produced individual studies of domestic deforestation independent of FAO and UNECE (WRI 1990). These studies provide recent and comprehensive data illustrating the situation in the respective countries.

Forest estimates

Estimates: In 1970, about 32 % of the land surface of the world was covered with forest and woodland (FAO 1987a). By 1985, forest and woodland occupied 31.24 %; a net loss of over 104 million hectares (approximately 1 million km^2). Only two regions reported increases in forest and woodland cover over the same time period: Asia gained almost eight million hectares and Europe reported an increase of just over five million hectares. All other regions reported net losses. South America and Africa reported the greatest losses, 62.2 million hectares and 46.2 million hectares, respectively.

Preliminary figures released by the FAO in an interim report presented to the Commission on Forestry in Rome in September, 1990, indicate an average annual deforestation rate of 17 million hectares over the last 10 years (Henninger 1990).

Forest data quality

Data Quality: While it is universally recognized that major forest conversion has taken place, specific estimates on the amount and on current rates of deforestation and afforestation are few and controversial. Insufficient historical data, lack of consensus on definitions and data-gathering techniques, and the subjectivity of data interpretation are impediments. Existing estimates are rife with likelihoods, estimations, suppositions, and guesses. Williams (Williams 1990a: 179) summarizes the problematic nature of calculating both historical and current deforestation:

> Crucial to a discussion of deforestation is the calculation of how much forest has been cleared. But the task is not an easy one. Even today, with all the modern aids of land use censuses and satellite imagery, there is no unequivocal inventory of contemporary woodland (Allen and Barnes 1985). If this calculation is a problem now, how much more difficult for past ages. ... No overall synthesis of reliable data is at hand. ... The best that can be done is to indicate the magnitude of likely change that could be expected to occur.

Data uncertainty

Williams' table of historical deforestation (Table 4, next page) reflects this uncertainty by providing high and low estimates of areas deforested. He recently estimated the margin of error in global deforestation over the past 300 years to be as high as 1,000,000 km^2 (an area more than double the size of Spain) (Williams 1990b).

Deforestation rates

Current deforestation rates could be derived by comparing data on land use under forest and woodland from the annual FAO reports. A comparison of the 1961-1965 data to that of 1970 reveals a large shift inconsistent with that of later years. This raises questions as to the accuracy of the data, particularly before 1970. FAO's inclusion in the *Production Yearbook* of land to be reforested in the 'foreseeable future' raises questions: when is the foreseeable future?, how does the FAO know there will be replanting?, and what proportion of the figures relate to this future planting?

FAO-UNEP (1982) forest data are better than those found in the FAO production publications because the data are qualitatively

Table 4: Estimated Area of Forest and Woodland Cleared (x 1000 km^2)

Regions or Country		Pre-1650	1650-1749	1750-1849	1850-1978	Total high estimate	Total low estimate
North America		6	80	380	641	1107	1107
Central America	H	18				288	
	L	12	30	40	200		282
Latin America	H	18				925	
	L	12	100	170	637		919
Oceania	H	6	6	6	362	380	
	L	2	4	6	362		374
USSR	H	70	180	270	575	1095	
	L	42	130	250	575		997
Europe	H	204	66	146	81	497	
	L	176	54	186	81		497
Asia	H	974	216	596	1220	3006	
	L	640	176	606	1220		2642
Africa	H	226	80	-16	469	759	
	L	96	24	42	469		631
Total highest		1522	758	1592	4185	8057	
Total lowest		986	598	1680	4185		7449

Source: adapted from Williams 1990b (confusing data for Europe, 1750-1849 in the original).

assessed. The forest data are distinguished by country in terms of the quality of its data (Lanly 1983; Rudel 1989).

WRI has the most comprehensive data set on forest land, reforestation rates, and deforestation rates, but it is not problem-free. WRI uses data adjusted by the FAO for 129 countries and compares them to the situation in 1980 (baseline); the ECE data are from the early 1980s but were not adjusted to a baseline year. The UNECE compilation does not detail what information-gathering techniques were used to complete the questionnaires and estimates. The FAO reforestation rates as reported in WRI have been criticized because the "trees are not seen for the forest" (trees planted in configurations that do not correspond to the definition of forest) (UNESCO 1989). Reforestation data may or may not include regeneration (either natural or through forest management) or trees planted for non-industrial use.

Perhaps most importantly, local experts are highly suspicious of many of the FAO and WRI data for specific locales. Harold Brookfield (personal communication) argues that the FAO figures for Malaysia are so poor that he will not use them in his assessment of land use change there. David Kummer, after extensive study of the issue on his part, notes the same for the WRI figures for the Philippines (Kummer 1990b, personal communication). Also, the WRI does not make it clear that "the 1980's" has two different meanings depending on the category of forest resources. For extent of forest and woodland, it means "the end of 1980 unless otherwise noted"; for deforestation and reforestation rates it means "1981-1985 unless otherwise noted" (Henninger 1990).

Forest assessments

Other Issues: In 1992 FAO and UNEP published the *1990 Forest Assessment*. They did not overcome the recurrent problems of definitions and data interpretation, but the report can be considered the most comprehensive source of data on forest cover, deforestation, and reforestation at the time. UNEP and FAO also made a comprehensive attempt to remedy the definition and data problems by compiling renowned experts' advice on the environmental parameters that are to guide future global forest assessment (UNEP/FAO 1993).

Any statement concerning global or regional forest cover, reforestation, or deforestation must take into account the variety of data sources, incompatible time frames, and varying definitions. The reliability of forest data is contentious, and drawing conclusions regarding any aspect of forest trends (other than simplistic ones) at the global or regional level is risky. Global statements will be of questionable value until exhaustive work is done at the country level, using common definitions and agreed-upon standards of coverage, quality, and accuracy.

Livestock

Livestock

Importance of livestock

Importance: Livestock is of interest in this global land use/cover change discussion for two major reasons: we want to know how much land is taken up for livestock production, and how many animals there are in total. Both are important because land for livestock production, and the excrements of the animals themselves, are linked into global nutrient cycles. From a purely ecological point of view, livestock production is a less efficient form of food production than is crop production in the sense that livestock are consumers of plants (primary producers), i.e., they are located higher in the food web and thus require a larger amount of "input" to provide equivalent amounts of food to the end consumer (people), albeit qualitatively different. In other words, one could theoretically feed more people with plant crops than with animal products. The simultaneous global tendencies of increasing world population on the one hand and a shift in eating habits toward consumption of more animal products, in particular meat, on the other hand therefore create a troublesome situation.

Farmers have to weigh many factors (market value for different products, cultural preferences, physical capabilities of the land, availability of technical know-how and other inputs) to arrive at a compromise between how much land they should devote to crop versus livestock production (although, as shown below, there is some overlap which makes data assessment very difficult). Global changes ranging from climate change to population pressures and changing economic forces are linked in an intricate manner to affect livestock production.

Livestock definition

Definition: Livestock refers to domesticated animals (non-pets) and their relationship to land used for their production and maintenance. It provides two areas of concern for global land use change:[2] the amount of land used for livestock rearing, and the total number of head of livestock (or land intensity of livestock). Some of the land covers used for livestock include: open pasture land (both improved and degraded), open land (meadows, marshes, tundra, steppe, savanna, desert), forest (open, closed, plantations), pasture (improved grasslands), and cropland (often during fallow periods, but also during crop growth). Typically, however, land cover/use associated with livestock is reported as either rangeland or pasture.

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[2] An obvious issue for this category is the usefulness of examining livestock or pasture/grassland. The latter is the typical land cover associated with major livestock rearing -- the land use. To be consistent with the land use emphasis of this module, livestock has been favored conceptually over grassland/pasture, but either emphases create problems. As noted in the section on cultivation, some lands used for that purpose are also grazed during the fallow season; hence a count of land cover would typically miss this land use. Likewise, a count of livestock does not necessarily inform us of the associated land cover.

Rangeland

Rangeland designates the land use of livestock production (WRI 1987, 1995), and constitutes areas that provide forage for free-ranging livestock and wild animals.[3] Rangeland may have physical limitations that make it unsuitable or uneconomical (at the time) for agriculture or intensive forestry, although many examples exist where livestock rearing and other land uses are compatible (agropastoral systems).

Permanent meadows
Pastures

Permanent meadows and pastures refer to land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). This use normally implies attempts to improve fodder conditions for animals, from burning to planting grasses.

Data on the extent and change in rangeland are sparse. Because rangeland includes a number of land covers, the calculations of rangeland can vary considerably from region to region. Systems of livestock herding (nomadism/ranching) also vary from region to region, making regional comparisons difficult. There are also conflicts about which land covers constitute rangeland. The total number of livestock is somewhat more comparable because there is not a great variation between the specific species of animals around the world. The data, however, are disaggregated by age or sex of animals. Also, when considering total numbers of head of livestock for methane production, one must consider what the changes have been in wild ruminant populations as well.

Livestock/rangeland
data sources

Sources: Knowledge of the extent, condition, and use of rangeland is incomplete: no comprehensive global assessment or data sets exist to our knowledge. The most complete analysis of rangeland has been done by the World Resources Institute (WRI) and the International Institute for Environment and Development in their

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[3] In this case, wild animals refers to non-domesticated animals that are used by humans. This potentially expands the area under rangeland by quite a bit in certain regions of the world.

World Resources Series (WRI 1990). They use data that have been gathered by the FAO and are published in their annual *Production Yearbooks* (FAO 1989a). In addition, they use data from the FAO/UNECE published in their *Forest Resources 1980* book (FAO/UNECE 1985).

The WRI's global, regional, and country estimation of rangeland is based on adding the total amount of FAO's permanent pasture plus all of FAO/UNECE's open forest land plus one half of FAO's "other land" category (WRI 1987). The permanent pasture (noted above) and other land data have been collected and published yearly by FAO since 1946. **Other lands** includes unused but potentially productive land, built-on areas, wasteland, parks, ornamental gardens, roads, lanes, barren land, and any other land not specifically listed under arable land, land under permanent crops, permanent meadows and pasture, and forests and woodland (FAO 1986a, 1994). The open forest land -- woodlands that have a relatively continuous grass cover on the forest floor and the canopy covers more than 5% of the area, but no more than 20% -- is based on 1980 estimates. Also this land must not be used primarily for agriculture or forestry (FAO/UNECE 1985).

Data for number of livestock are gathered by the FAO and published in their annual *Production Yearbook*. The data for the FAO *Production Yearbooks* come from official figures supplied by governments through questionnaires or from government publications and reports to the UN or FAO. When official figures are not available, data are taken from "reliable," unofficial sources, or are estimated by FAO and are indicated as such. As with the forest data, the definitions used by reporting countries vary considerably, and items classified under the same category often relate to greatly differing kinds of land (FAO 1989a). As a result, the land use data collected by the FAO are not completely compatible, and the aggregate estimates are rough. These data, however, are perhaps the best on a world-wide basis.

For historical changes, John Richards (Richards 1986; Richards 1990) uses the WRI's data and FAO data (as noted above) as well as reconstructing vegetation from soil studies (Houghton *et al.* 1983; Richards, Olson, and Rotty 1983) and estimating agricultural land from world population (McEvedy and Jones 1978). The WRI has created historical land use data by extracting from vegetation maps and determining rangeland in combination with population and growth estimates (Richards 1990; WRI 1987, Table 18.3).

Livestock/rangeland estimates

Estimates: According to the WRI, the amount of rangeland world-wide in 1983 was 67 million km^2 or 51% of the total ice-free land area of the earth. Of this total, permanent pasture is 31 million km^2 or 24% of the total ice-free land area (WRI 1987). According to *FAO Production Yearbooks*, permanent pasture land has changed from 30.46 million km^2 to 33.62 million km^2 between 1965 and 1994. Regionally, according to FAO data, the world has not experienced much change in the quantity of permanent pasture, except perhaps Asia.

Ruminants

Domesticated animals

The total number of domesticated ruminants[4] world-wide as of 1994 was 3,152 (in millions of individuals) (FAO 1994). The total number of all domesticated animals in 1994 world-wide was 16,957 (in millions of individuals). The total number of ruminants has changed from 2,583 to 3,152 (in millions of individuals) between 1965-1994. Regionally there have been few changes, except perhaps in Asia An important aspect of analyzing both the pasture land and livestock data is that the two do not vary together. Livestock numbers have been increasing at a greater rate than pasture land.

Livestock data quality

Data Quality: Quantifying the extent of rangeland is difficult because of overlapping definitions of lands that provide forage; different studies include different land covers for forage. Problems also arise owing to multiple land use and changes in these uses per unit of land and time. For example, some forests are closed to livestock, some pasture land is left fallow for years, and some areas are only used during part of the year. Since each country may count these units different, the potential error in comparisons is large.

The aggregate numbers for rangeland probably underestimate forage area because they do not necessarily consider the land area from which extensive biomass used for forage is obtained, including seasonal browsing areas (i.e., forage land used only during certain times of the year) or peasant fodder systems, such as "backyard" livestock fed on crop residues. In addition, the aggregate numbers hide the regional differences in rangeland conditions, productivity, and intensity. This requires us to consider: land area under different covers used for forage, total forage production, and total land used.

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[4] Ruminants include cattle, buffalo, camels, sheep and goats. Domesticated animals are all ruminants plus pigs, chickens, ducks, and turkeys (after *FAO Production Yearbook 1986)*.

The *FAO Production Yearbook* data compiled in the 1940's and 1950's are not as accurate as the data from the 1970's and 1980's. This is because the earlier data were based more on general estimates that vary widely. In addition, the earlier data were not recorded for the same year for each country, and therefore it is difficult to ascertain change for aggregate numbers. The aggregate numbers in the WRI's rangeland data are rough estimates; they may be appropriate at the global level, but regionally there are difficulties. WRI claims that one-half of FAO's "other land" is rangeland. Yet one-half of Algeria's "other land" is desert, while this half for Sweden is tundra where reindeer forage. For the historical reporting that the WRI and John Richards provide, there are problems of arriving at a new estimate from sources that also estimate data (WRI 1987; Richards 1986).[5] This leads to the problem of compound error.

Regional issues

North America

Other Issues: The most complete data on regional range conditions and changes are for North America. This is because the rangeland has been intensively used only for the past 100 to 150 years and because the U.S. government has kept extensive statistics (US Congress 1982; Stoddart *et al.* 1975; US Forest Service 1980). When the western part of the United States was opened to livestock, overgrazing lead to degradation of much of the land. Laws in the post-Dust Bowl era have helped improve the rangeland so that now it is in better overall condition than it has been in any time this century (BLM 1985). The U.S. has 312 million hectares of rangeland (WRI 1995). Earlier indications of its quality are as follows : 32% in good, 28% in fair, and 12% in very poor condition (US Forest Service 1980). Canada has followed similar paths as the United States.

Latin America

Three types of rangelands are recognized in Latin America: (1) natural grasslands, woodlands and savannas; (2) high-elevation natural grasslands and shrub lands; and (3) cultivated pastures, established in areas once occupied by forests. About 70% of the rangeland is in the first category (WRI 1990). Much of the rangeland of Latin America has been overgrazed and degraded like that of the North. The greater Amazonian region has amassed much concern because of short-term pasture created from tropical forests. The principal countries with rangeland includes: Argentina, Paraguay, Uruguay, and Brazil. Rangeland covers about one-third, or 700 million hectares, of Latin America's land surface. Permanent pasture land occupies about 569 million hectares (WRI 1990).

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[5] John Richards creates new estimates for the extent of agricultural land based on estimates of population by McEvedy and Jones (1978).

Australia

Australia has a similar history to North America in terms of settlement, introduction of European species, and overgrazing of rangelands. Much of Australia's rangeland is arid and is easily disturbed. A unique problem to Australia was the introduction and subsequent overpopulation and overgrazing of the European rabbit. According to the *FAO Production Yearbook*, in 1993 Australia had 413.800 million hectares of pasture land (FAO 1994).

Africa

About 65% or 1,945 million hectares of Africa is rangeland (WRI 1990). Much of Africa's rangeland has complementary and competing land uses such as, respectively, cropland used for seasonal grazing, and wildlife reserves and fuelwood supplies in which grazing takes place. Like parts of Asia, Africa's long history of pastoralism, nomadic or other forms, has claimed almost all dry forest, savanna, and semi-xeric and xeric lands for livestock production, if only for brief periods of time throughout the year and for relatively few livestock (per unit area of land). Much of this area is also the grazing domain of large herding animals.

Europe

Thirty-three percent of Europe is rangeland, including open land and open forest. Of this, highly productive permanent pasture land makes up 18% (WRI 1987). Most of Europe's pasture land is intensively managed and is, on the average, the most productive in the world.

Middle East and Central Asia

The Middle East and Central Asia have an ancient tradition of livestock grazing, primarily through various forms of nomadism. Rangelands, therefore, account for a large percentage of the land area in this region. Interestingly, this area has some of the driest continually grazed areas in the world (WRI 1987, Table 5.8). According to the *FAO Production Yearbook*, in 1986 the Middle East had 267.652 million hectares of pasture land (FAO 1987a).

Asia (incl. Siberia, India, China and Mongolia)

Asia, including all lands from Siberia into the Indian subcontinent, has the most varied rangelands in the world (including: tundra, steppe, desert grasslands, opened monsoon forests, tropical forests). The People's Republic of China and Mongolia have over half of Asia's permanent pasture lands (FAO 1994). China has about 400 million hectares of permanent pasture; Mongolia has 125 million hectares of permanent pasture land (World Bank 1984; FAO 1987a, 1994). On the Indian subcontinent permanent pasture land makes up 11.4 million hectares or about 4% of land surface and permanent pasture. About 49 million hectares of other land can be considered rangeland (FAO 1987a). Much of the rangeland in the subcontinent has been overgrazed and degraded. There are, however, some successful programs in managing the common rangeland and rehabilitating lands (WRI 1988).

Settlements

Settlement

Importance: Wherever you settle, travel, or set up shop -- you take up a portion of the earth's surface. So what? -- you may say. It seems entirely inevitable. Yes, and no! It is inevitable that you place yourself somewhere, but people the world over make all kinds of choices, however constrained, as to how they live: whether they live in rural or urban or suburban areas, whether they live in small or big dwellings, in straw-and-clay huts or in concrete multi-apartment complexes, close together or far apart. All of these choices result in settlement patterns that are in various ways linked to global changes -- environmental as well as anthropogenic. As is discussed further below, there is a global tendency toward urbanization; large urban centers create as many opportunities (jobs, education, cultural exchange) as they create problems (air and water pollution, localized climatic and watershed changes, sanitary/public health problems, traffic jams, social tensions and criminal activity). Rapid urban growth in particular brings with it problems that result from inadequate infrastructure and planning, establishment of shanty towns/slums along the city fringes, urban sprawl onto productive agricultural land or hazardous areas, and so forth. Often accompanying urbanization is the depopulation of the countryside, frequently associated with land degradation, loss of agricultural productivity, decline of attractiveness of rural life, and cessation of the provision of services in rural areas. Settlement data over time and space thus give an indication of these tendencies in different regions of the world.

Importance of settlement

Definition: Settlement refers to the land used for human habitation. In land use/land cover classifications such as that of the US Geological Survey, this area is referred to as urban or built-up land. In the USGS system, this category includes cities, towns, villages, strip developments along highways, transportation, power, and communication facilities, and industrial, commercial and institutional sites (Anderson *et al.* 1976, cited in Lillesand and Kiefer 1979).

Settlement definition

Sources: Reflecting the dominant interests of researchers and policy makers, data are readily available on urban populations, but not on the area occupied. Occasionally, works on global environmental change include estimates of the planet's urbanized area, but the reliability of these estimates is questionable. Some researchers have estimated settlement area by extrapolation from

Settlement data sources

urban population numbers.

International agencies such as the United Nations and the World Bank publish voluminous data on global population, including estimates of the urban portion of the population. The main data sources include the UN's *Demographic Yearbooks* and *World Population Prospects Reports*.[6] The *Demographic Yearbook* for 1988, gives urban population by country for each year between 1979 and 1988 (UN 1990). A special edition published in 1979 summarizes population data by year from 1948 to 1978 (UN 1979). All of this information is based on census data supplied to the UN by national governments. The Population Reference Bureau (PRB) is considered by some to be the authoritative source on population, but it also draws heavily upon UN data. In addition, a variety of general urban studies and case studies on urbanization have been published. For example, the World Commission on Environment and Development commissioned four background papers (Burton 1985; Hardoy and Satterthwaite 1986a; Hardoy and Satterthwaite 1986b; Sachs 1985). Some of these studies include data on urban areal extent, but these data do not appear to have been compiled.[7] Chandler (1987: 6-7) mentions that in the case of compiling his historical database on urban populations he sometimes used city area to calculate population;[8] he does not, however, publish areal data. Another useful, but incomplete, data source is research estimating the conversion of agricultural land to urban and other non-agricultural uses.[9]

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[6] For example, the World Bank's 1990 *World Development Report* gives tables of urban population (as percentages) and changes between 1965 and 1988; the main sources are the UN's *Prospects of World Urbanization* (UN 1988) and its report, *Patterns of Urban and Rural Population Growth* (UN 1980).

[7] An example of data available in case studies is provided by Brown and Jacobsen (1987), who give the population (P) and area (A) of Sao Paulo for the years 1930 ($P = 1$ million; $A = 150$ km^2), 1962 ($P = 4$ million; $A = 750$ km^2), and 1980 ($P = 12$ million; $A = 1400$ km^2). They also note that, in the mid-1980s, Hong Kong's population was 5 million and its area 1000 km^2 including extensive urban agriculture.

[8] As delineated by city wall. Except in Britain, walls encompassed virtually all cities until 1890.

[9] See, for example, Crosson (1982) for the United States.

Settlement estimates

Estimates: Estimates of the extent of land occupied by human settlements have been made by researchers of global environmental change, by extrapolating from urban population numbers, and locally in case studies. Within this context, L'vovich, White, and collaborators (1990: 246) estimated that the mid-1986 urban population of approximately 2.2 billion, "including industrial enterprises and roads, occupied an area of about 1.2 - 1.4 million km^2." Earlier, in an article on anthropogenic albedo changes, Sagan and colleagues (1979) assumed an urbanized population of one billion, and estimated global urbanized area at one million km^2, or about 0.2% of the earth's surface; they estimated the annual rate of change as 20,000 km^2, or about 0.004% of the earth's surface.

The magnitude of urban populations and an example of the type of data available are illustrated by the following figures. The UN report, *World Population Prospects as Assessed in 1982* (UN 1985), gives estimates and projections of urbanization, urban and rural populations (in absolute numbers, percentages) and population density -- from 1950 to 2025 (see Table 5). These data are available by country and region, and as world totals. The Population Reference Bureau's mid-1990 estimate of global urban population was 2.18 billion (PRB 1990), up from 600 million in 1950 (Brown and Jacobsen 1987).

Urban and rural population estimates and projections

Table 5: Urban and Rural Population Estimates and Projections

Year	Urban ($x10^6$)	Rural ($x10^6$)	%Urban	%Rural	Density (km^2)
1950	735	1769	29	71	18
1960	1013	2001	34	66	22
1970	1361	2322	37	63	27
1975	1561	2515	38	62	30
1980	1776	2678	40	60	33
1985	2013	2829	42	58	36
1990	2286	2962	44	56	39
1995	2599	3081	46	54	42
2000	2952	3175	48	52	45
2010	3761	3236	54	46	52
2020	4654	3152	60	40	57
2025	5107	3070	63	37	60

Source: UN. 1985. *World Population Prospects as Assessed in 1982*; data extracted and derived from various tables.

Settlement data quality

Data Quality: The reliability of global estimates is questionable. L'vovich and White (1990) do not explain how their estimates were derived. Sagan, Toon, and Pollack (1979) freely admitted that it is impossible to estimate global land use changes to an accuracy greater than a factor of two. Their estimate was based on work by Wong (1978), who extrapolated urban area from urban population. Wong, citing Pire (1976) for a portion of his methodology, claimed that the average California city dweller requires 1,000 m^2 of urban space, each urban Briton 600 m^2, and therefore, the average urban dweller uses 800 m^2 (Wong 1978). Such a methodology is obviously inadequate. A single conversion factor is not suitable, given spatial and temporal differences in urban patterns, to say nothing of cultural variability.[10]

Further problems also arise from the use of urban population figures to extrapolate area. Some increases in urban population numbers reflect changing urban boundary delineations as well as actual increases within a particular space (cf. WCED 1987: 258, note 4). Researchers who use data sources other than aerial photography or satellite imagery are likely to run into this problem of municipal boundaries. The jurisdictional limits of a 'city' or other data-reporting unit will not necessarily reflect actual land cover or land use.[11]

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[10] There have been some attempts to use remote sensing data to track land use changes associated with urbanization: for example, an NTIS newsletter reports on a Utah study which tested the use of Landsat MSS data as a means for detecting conversion of agricultural land to urban land use (NTIS 1985). It is not known how much coverage of urban areas is available of how many such analyses have been done. Aerial photography provides an excellent means of tracking urbanization trends; the USDA, for example, commissioned a 1976 air photo study of 53 US counties (Zeimetz 1976). Coverage is expensive and therefore probably very spotty; it is also difficult to track down, especially on a global scale.

[11] For example, the overview of Third World cities by Hardoy and Satterthwaite (1986) highlighted several interesting issues. They note that many cities -- including Sao Paolo, Bombay, Delhi, Bangkok, Manila -- contain hundreds or thousands of hectares of undeveloped land which is being held by speculators; on the other hand, in Colombia, speculators are causing the rapid urbanization of the best agricultural land. In Egypt, over 10% of the prime agricultural land has been urbanized, mostly by squatters and by subdivision. Since 1990 the Delhi urban area has increased thirteen-fold, eating up over 100 agricultural villages, and including the phenomenon of using topsoil to make bricks. Official enumeration boundaries may not reflect these changes as they occur.

More detailed concerns are raised by UN documents. According to the 1988 *Demographic Yearbook*, the major constraints on data reliability for urban population estimates are under-enumeration, distinguishing *de jure* and *de facto* populations and varying definitions of urban; the latter is the most significant factor, seriously limiting comparability (UN 1990). What is considered 'urban' varies according to each national census; the various definitions are listed at the end of each UN table. An impressionistic review of the definitions in the 1979 and 1988 editions indicates that in the 1980's most nations considered settlements with 2,000-5,000 residents as the minimum threshold for being urban; however, some nations simply list the population of the specific towns declared to be the nation's urban areas. In the 1950's, the minimum threshold ranged from towns of several 100 for some countries to towns of 1,000-2,000 for most nations, and to towns of 5,000 for a few developed countries.

Another implication of relying on national census data is that actual counts are only available for the years in which a particular country happened to conduct a census. The yearbooks do give references for earlier censuses, even those predating the founding of the UN; the 1988 yearbook, for example, gives references going back to 1920. The 1979 special edition lists, by country, years for which urban census data are available and gives urban definitions by country by census year (UN 1979).

Wetlands

Wetlands

Importance of wetlands

Importance: In considering the first four types of land cover/use, it may be obvious to you why we would want to find the best data available. But why wetlands? Compared to cropland, rangeland, or forest, wetlands cover much less of the earth's surface. To be crucially important, however, a land cover doesn't have to rank high in areal extent. Wetlands -- both saltwater marshes and freshwater wetlands -- are among the most biologically diverse habitats on earth. Furthermore, coastal wetlands play a fundamental role in the life cycle of many marine species and thus are linked to the productivity of coastal and marine fisheries; they provide refuge for many bird species and are an essential buffer against coastal hazards (floods and storms). Wetlands are also among the environments most threatened by agriculture, urbanization, and water pollution. Global warming which scientists believe will lead to a significant rise of sea level adds the threat to coastal wetlands of flooding and resulting destruction. Human development along the edges of wetlands leaves them no place to migrate as the sea encroaches on the land. Wetlands fulfill a number of essential ecosystemic functions from which humans benefit in myriad ways -- reason enough to make every effort to find accurate and complete data.

Wetlands definition

Definition: Wetlands may be defined as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface of the land or is covered by shallow water" (Cowardin *et al.* 1979; also Orme 1990). Comprising an ecotone between dry land and aquatic ecosystems, albeit one with unique ecological characteristics, wetlands form a continuous gradient between the terrestrial and the aquatic, and the upper and lower boundary limits in definitions are, therefore, arbitrary. For example, flood frequency has been a source of controversy in US definitions; other US controversies occur over the type, sizes, location, and conditions that may be defined as wetlands. Thus, there is no universally accepted definition, and those that are used, tend to be colored by the purpose of the agency using them (Mitsch and Gosselink 1986).[12]

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[12] The US Army Corps of Engineer's definition is: "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (cf. e.g., US Corps of Engineers 1987).

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Wetland data sources

Sources: No authoritative global database on wetlands is indicated by the literature. Very few global estimates of wetland extent or loss appear to have been published at all. In general, it seems that wetlands became a major issue only in the 1970's, when some countries instituted national wetland inventories (Williams 1990b). There is no indication in the literature that any global agency is monitoring these national compilations; it is not even clear that very many countries are doing inventories. The United States has the most complete wetlands data (Williams 1990b); but "little progress has been made outside North America and especially in the Third World" (Maltby 1988: 6).

Losses are especially difficult to estimate. Even in the US, accurate baseline data really only date to the mid-1970's, and there has been "no comparable comprehensive national survey elsewhere" (Maltby 1988: 6). Large European losses appear in the historical record for specific regions or locales. For the rest of the world, data come from case studies (see, for example, Williams 1990b), although region-wide compilations have been made for some regions (e.g., Carp 1980; Karpowicz 1985; Scott and Carbonell 1986; Scott 1989).

The World Resources Institute's 1990-91 world data "Wetlands/Marsh" category can be found in its "Habitat Loss, 1980's" table (WRI 1990, Table 20.4). This table pieces together data from a number of local and regional studies. The table lists data by country; these entries are not summed into continental or global figures. Elsewhere in the literature, the most widely cited figure (see below) for the areal extent of global wetlands is that of Maltby and Turner (1983). This estimate was published without citations in a popular magazine. It was apparently based on biogeographical information compiled by Soviet geographers (Bazilevich, Rodin, and Rozov 1971); this, in turn, is based on a 1964 Soviet atlas. These figures were later reworked by Mitsch and Gosselink (1986). Another Soviet figure (see below) appears as an estimate of "marshland" in the context of a study on global water storage/water balance (UNESCO 1978).

Wetland estimates

Estimates: Maltby and Turner (1983: 13) estimated total wetlands for eleven "thermal belts and bioclimatic regions" of the globe, and concluded that wetlands comprise 6.2% of the earth's land area, or 8,228,000 km^2. Mitsch and Gosselink (1986) reworked these figures, making more consistent use of the Russian data from which they were derived; their estimate placed total world wetlands at 8,558,000 km^2 or 6.4% of total land area. These figures are still cited (Williams 1990b). Apparently using a more restrictive definition, the Soviet water balance study for UNESCO estimated "marshland" at only 2,682,000 km^2, or 2% of the earth's land surface (UNESCO 1978).

Much concern is expressed about the extent and rate of wetland loss, but estimating this is very difficult given the state of current inventories and lack of baseline data. The World Resources Institute's compilation of data led them to estimate a 50% global loss of wetlands --presumably in the 1980's, although this is not made clear. Nor do they explain how the 50% loss figure was derived; however, totaling the WRI estimates gives 4,106,541 km^2, or 49.9% of Maltby and Turner's 8,228,000 km^2 figure calculated from the 1971 Russian figures.

According to Maltby (1988), the greatest potential for future wetland losses to development lies in the Third Word, where pressures to increase agricultural land and reduce water-borne diseases combine with irrigation and hydroelectric projects to threaten wetlands.

Wetlands in the U.S.

Some of the problems inherent in estimating current wetlands and wetland loss are illustrated by the case of the United States, the acknowledged leader in wetland inventory and study (Maltby 1988). Between 1907 and 1987, fourteen different estimates have been made, with little agreement (Williams 1990b). Two definitions of wetlands are used by the US government. The Fish and Wildlife Service definition is used for scientific work, inventory, mapping and classification, while the Army Corps of Engineers/Environmental Protection Agency definition is accepted by managers and regulatory agencies (Mitsch and Gosselink 1986). In the mid-1970's, the first definition resulted in a 99 million acre (or 40,095,000 hectares) US wetland inventory; the second definition resulted in one of 64 million acres (or 25,920,000 hectares) (U.S. OTA 1984). Loss estimates are similarly variable, depending on the agency doing the estimating (Horwitz 1978); the Council on Environmental Quality estimates a long-term loss of 53% (CEQ 1990), while other loss estimates were in the 30-40% range. Loss estimates are further complicated by the creation of artificial wetlands, although it is not clear that these can replicate the functioning of natural systems (Gosselink and Maltby 1990).

Wetland data quality

Data Quality: Some of the World Resources Institute's figures are based on regional research specifically concerned with wetlands (e.g., Carp 1980; Karpowicz 1985; Scott and Carbonell 1986; Scott 1989; Canada 1988). Some data are taken from the FAO's agro-ecological zones project (FAO 1978); however, there are no data for some nations, and definitions of 'wetland' are inconsistent across countries. The WRI cautions that their figures probably underestimate actual wetland extent.

The Maltby and Turner (1983) estimate has several major problems. First, it is based on research done by Bazilevich, Rodin, and Rozov (1971) for the purpose of quantifying plant productivity (biomass production) in different geographical regions. These regions are taken from the soil and vegetation maps in the Soviet *Physical-Geographic Atlas of the World (1964)* (American Geographical Society 1965). None of the assumptions made in the atlas or in the estimates by Bazilevich and colleagues -- or their implications for wetlands -- are made explicit.

Second, Maltby and Turner (1983) were inconsistent in deciding which of the Soviet bioclimatic vegetation categories to include as wetlands and which to leave out; some forests with small bogs were included, others were not. They also classified floodplains and humid tropical meadows as wetlands. The revised estimates by Mitsch and Gosselink (1986) corrected this second problem but not the first.

Surface Water

Surface water

Importance: Behind the plain term "surface water" lie many essential ecological functions, amenities, and human uses that link in multiple ways to regional and global environmental changes. Water in an ecological sense is arguably the most essential medium enabling the life processes of organisms and is crucially involved in other physical processes in the environment. Surface water bodies encompass a number of aquatic and shoreline habitats, some of which host rare species; water bodies often result from and affect local to regional climates; and as migration routes, water bodies, link distant habitats and environments. In terms of amenities and human uses, surface water bodies are closely linked with tourist and recreational activities, commercial and recreational fisheries, trade, transportation, the production of electricity, and industrial activities that require abundant water supplies. Water bodies are also connected with processes like liquid waste disposal and water pollution, flooding, and the breeding and spreading of bacterial and other diseases. Urbanization, development, agriculture, transportation, and industrial activities like mining, nuclear power production, aluminum smeltering, and paper production all depend on surface (and ground-) water. In some regions of the world, surface water even augments groundwater supplies for drinking water, emphasizing the importance of maintaining high water quality. Because of water's essential role in all of these processes, some water resource and global change scientists believe that the land cover most important in future discussions of global resource use and change will be water (see e.g., Gleick 1994, 1990; Luterbacher and Guner 1996).

Importance of surface water

Definition: For the purpose of this assessment, surface water is defined as inland water as represented by lakes, rivers, reservoirs, and ponds, but not wetlands (see above). It also does not include glaciers or the coastal bays and inlets classed as 'inland water' by official territorial boundaries.

Surface water definition

Sources: Given that every encyclopedia and atlas lists the area of each nation, and given that water is so easily visible in the infrared bands of remote sensing platforms, one might assume that data on the areal extent of surface water would be readily accessible. According to hydrologist Harry Schwarz (personal communication) it is not, however, probably because there is not a demand for data on surface area; water resources experts are interested in volume not

Surface water data sources

area, and national surface areas are calculated on the basis of territory controlled, violating the limitation on 'inland water' (see *Definition* above).

It is surprisingly difficult to derive even a one-time tabulation of total surface water for the globe. There does not appear to be any ongoing monitoring of changes in the areal extent of surface water, nor is there a single agreed-upon baseline figure to compare such changes against. UNESCO's 1978 *World Water Balance* comes the closest to being an authoritative source.

The surface areas of large lakes and inland seas are published in atlases and similar references such as the CIA's *World Factbook*; accuracy and measurement methodologies change, however, so these data cannot be used as time series. The *World Register of Dams* lists surface areas of large reservoirs. Fairly complete hydrological data, including surface areas, are available for North America, Europe, parts of Asia, and Australia, but not the rest of the world (L'vovich 1979). Although they comprise a significant area, data on small water bodies -- natural and artificial -- is not generally available (Nace 1970; L'vovich 1979).

Surface water estimates

Estimates: According to Nace, a foremost US expert, "inland water areas of the world probably exceed 1 million km^2"; however, "only very crude estimates are available" (Nace 1970). These estimates follow by categories.

Lakes

Lakes: Natural lakes comprise the largest inland surface water area. UNESCO (1978: 43) estimated the area of the world's lakes at 2,058,700 km^2, or about 1.4% of the earth's total land area; of this, 1,236, 400 km^2 is fresh water and 822,300 km^2 is salt water. Globally, UNESCO identified 145 large (over 100 km^2) lakes and estimated that they cover 1,300,000 km$^{2;}$ they are thought to contain over 95% of total water volume (UNESCO 1978). Citing "USGS" as their source, Botkin and Keller (1987) give the global surface area of freshwater lakes at 855,000 km^2.

The significance of small water bodies is illustrated by a Soviet example. Bochkov, Chebotarev, and Voskresensky (1972) estimated that the former USSR has 2,850,000 lakes with a total surface area of about 500,000 km^2 -- about 2% of the country. More than 98% of these are small lakes less than 1 km^2; the total area of the 17 large lakes with a surface area over 1,000 km^2 is 173,000 km^2

(Bochkov, Chebotarev, and Voskresensky 1972), but those lakes contain over 98% of water volume (UNESCO 1978).

Reservoirs

Reservoirs: The most significant land use change affecting surface water is the creation of reservoirs. Petts (1984: xiii) noted the magnitude of this only recently appreciated human impact: "without doubt the damming of rivers has been one of the most dramatic and widespread, deliberate impacts of Man [sic] on the natural environment." As with lakes, global data are available for large dams and reservoirs -- which hold most of the water -- but the many small structures are not well-documented (L'vovich 1979).

Several estimates of the total water surface of global reservoirs have been made. A 1972 estimate put the total at 600,000 km^2; not counting the lakes included in backwater lake areas, the total water surface for reservoirs proper was estimated to be 400,000 km^2 (UNESCO 1978). L'vovich, White, and colleagues (1990) gave two estimates of the maximum water surface of global reservoirs. Apparently referring to reservoirs of more than 100 million m^3 capacity built since 1951, they estimated global reservoir surface area at 590,000 km^2; they also cited Voropaev and Avakian's (1986) estimate of the surface area of all large reservoirs when full as 390,000 km^2.

The 1972 UNESCO approximation of reservoir surface area was based on an estimated 10,000 reservoirs, mostly in Europe, the former USSR, and North America (UNESCO 1978). UNESCO also reported a total of 143 reservoirs with a capacity greater than 5 km^3 volume (UNESCO 1978). L'vovich (1979) cites the estimate of Avakian and Ovchinnikova (1971) that there were 1,350 large reservoirs (with a storage capacity greater than 100 million m^3) in 1971, as well as thousands of smaller ones, perhaps numbering 10-20,000. A *World Register of Large Dams* -- describing dams higher than 15 m -- has been issued by the International Commission on Large Dams periodically since the early 1970's (SCOPE 1972; van der Leeden 1990). The vast majority of large dams are in North America (Beaumont 1978). Although the land areas flooded by dams through history is not known, several authors have traced the history of dam building. SCOPE (1972) noted centuries of small lake construction such as the tanks of Sri Lanka and the fish and mill ponds of Europe. Lakes larger than 100 km^2 surface area were not built until 1915 when new concrete and earth moving technologies became available. By 1970, at least 40 reservoirs had been built which covered more than 1,000 km^2 and 260 between 100-1,000 km^2 in area were in operation all over the world -- as well as countless small dams (SCOPE 1972).

Beaumont (1978) identified three distinct periods of worldwide dam building between 1840-1971. Before 1900, there was increasing building activity, but the overall impacts were still relatively small. From 1900 to 1945 there was moderate activity, concentrated mainly in North America, W. Europe, SE Asia, and Japan, with gaps during wars and the depression. Between 1945 and 1971, 8180 major dams were built; this "phenomenal burst of building activity" peaked in 1968 with the commissioning of 548 structures. During 1962-68, more than 200 large projects were completed each year (Beaumont 1978: 40).

Rivers

Rivers: No estimates of flowing water surface areas were noted in the literature; interest centers on measures of volume and flow. In theory, surface area could be calculated from existing data (in well-inventoried regions) on stream, river, and canal miles by using approximate width values based on stream order and, for canals, engineering or navigational data.

Surface water data quality

Data Quality: A number of data problems have already been mentioned. Surface water data are limited by a lack of interest in areal data, lack of monitoring at the global level, and a lack of baseline measures. Changing accuracy standards and measurement methodologies preclude the use of published figures for estimating changes through time. In addition, data are more complete for industrialized nations and for large water bodies. Information theoretically available from hydrographic offices may be very time consuming to compile.

Even when data are available, a number of definition and measurement problems remain. For example, our definition of inland water does not address the boundary problem posed by estuaries or coastal wetlands. Inland, other problems are posed by fluctuating water levels and ephemeral water bodies. Most natural water bodies fluctuate so little in size (UNESCO 1978) that changes in measurement accuracy would probably overshadow actual variations (H. Schwarz, personal communication). However, closed-basin lakes -- which include some of the world's largest -- may vary in area by a factor of 4 to 10 (UNESCO 1978). L'vovich (1979) gives a number of examples. This variability could serve to skew aggregate data.

Many reservoirs fluctuate seasonally -- by as much as 40-60% -- depending on whether they are full or drawn-down (H. Schwarz, personal communication). Some data sources record maximum area, others average area.

A historical note on areal measurement is also instructive. Until very recently, calculating areas from maps was an arduous process; lake areas were often estimated by treating the water body as if it were rectangular. Comparing Russell's US Lake Survey (1895) with Greswell and Huxley's lakes and rivers encyclopedia (1965) shows similar concerns about measurement and rectangularity. This has obvious implications for the use of historical data in time series.

Finally, while remote sensing data on water body area is readily available in principle, the cost of image processing and gaps in coverage mean that the information is not necessarily accessible.

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2

Land Use/Cover Data --

Instructor's Guide to Activities

Conceptual Understanding → **Problem Formulation** → Data Acquisition and Assessment → Data Analysis → Interpretation of Results

Goal

In this first set of activities (Activities 2.1 and 2.2), students are taken through the iterative process of formulating a "researchable" problem within land use/land cover studies, getting an understanding of the need for precise problem formulation and the impact of different problem formulations on research design, data acquisition, analysis, and the answers that one can find.

Learning Outcomes

After completing this set of activities associated with Unit 2, students should:

- have an understanding of the typical (if idealized) process of scientific research;
- be able to formulate a "researchable" problem; and
- understand the impacts of different problem formulations.

Choice of Activities

It is neither necessary nor feasible in most cases to complete all activities in a unit. Instead, select at least two or more from each unit, covering a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

2.1 What's the problem anyway? -- Step-by-step research problem formulation
2.2 Getting wired for global change research -- Flow chart completion

Suggested Readings with Guiding Questions

The suggested readings for this activity refer both to "the problem," i.e., land use/cover change and to the "formulation" of research problems.

- *Background Information*, Introduction of Unit 2

  Note: the *Background Information* of Unit 2 is quite lengthy and tedious at times. We suggest that the class be divided into six groups, each focussing on

one of the discussed land use/cover types and their associated data issues. Each group prepares a short (5 minute) summary to be presented by one student during the class session (instead of a lecture).

☐ What is **the problem** with global environmental change?
☐ What are the problematic issues? For whom?
☐ Why bother to find consistent, comparable, continuous data series?
☐ Would we have a problem if we had perfect data?

- Ojima, D.S., K.A. Galvin & B.L. Turner II. 1994. The global impact of land use change. *BioScience* 44, 5: 300-304.

  ☐ How is land use/cover impacted by other global changes?
  ☐ How does LULC change impact other environmental and human spheres?
  ☐ What don't we know about LULC change? And so what?

- Brunner, Ronald D. 1991. Global climate change: Defining the policy problem. *Policy Sciences* 24, 3: 291-311.

  This is a critical piece on the issue of who sets what kind of research and policy agenda, written more from a political rather than scientific point of view. Students might require some background understanding that global change is a contentious issue. If you decide not to assign this reading, make sure students learn that it is in some other way.

  ☐ Is global climate change "real" or is it merely a political problem?
  ☐ Who are the players in this game?
  ☐ Who sets the research and policy-making agenda? Who is left out?

- Berg, Bruce L. 1995. *Qualitative research methods for the social sciences.* 2nd ed. (1989), Allyn and Bacon: Boston, MA. Chapter 2 "Designing qualitative research" (provided).

  The chapter from this introductory text on social science research methods gives students some background on the critical importance of problem formulation. If the chapter is used, you should guide undergraduates through the reading. Alternatively, use this or a similar text as lecture material.

  ☐ How do you best formulate a research question?
  ☐ What difference does it make how you formulate it?

Activity 2.1 What's the problem anyway???

Goal

Students learn in a step-by-step fashion to formulate researchable questions, considering issues of time and data constraints, finding appropriate variables and measures, and uncovering underlying assumptions.

Skills

- ✔ connecting macro forces, proximate sources of change and LULC change in a research problem
- ✔ depicting underlying assumptions in LULC research questions
- ✔ determining appropriate measures for the variables of interest
- ✔ analytical thinking
- ✔ group discussion and communicating

Material Requirements

Student Worksheet 2.1 (provided)
Suggested or alternative readings

Time Requirements

1 class session (45-50 minutes)

Tasks

Students should have had some background readings on "problem formulation" at this point. Instructions are provided below for each question.

A, B Students read through questions **A** and **B** on the *Student Worksheet 2.1* and discuss in small groups[13] how LULC is related to global change and what we would really like to know about this relationship. They should end up with a succinct short (written) formulation of the problem (problem statement). The instructor (and teaching assistant, if available) go from group to group to support and stimulate this problem-stating process.

Instructors should assign individual students to roles during this discussion, such that there is a leader, a reporter, and a process-observer. If you have used small group discussion before, make sure students have different roles than they had previously.

Then groups should collect three to five research questions (one or two each) that directly address the research problem as formulated in the group's problem statement. If they find more than five questions, they should write down those five that are most important to them, and note why those particular five have been chosen.

It is advisable that the instructor demonstrate this process briefly beforehand with an example of his/her own research. Mention assumptions like "growth is good," "nature knows best," or "new technology solves problems." Then have students work on operationalization according to the example provided on *Student Worksheet 2.1*.

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[13] The group size depends, of course, on the overall class size. It is recommended to not let the groups be larger than four unless students are used to small group discussions and have the necessary communication skills. See *Notes on Active Pedagogy* for further hints on group work.

Don't let either part of this exercise go on for more than 8-10 minutes each. See *Supporting Material 2.1* for an in-class illustration of the first two questions of this activity.

Take a short time to discuss the implications of the problem statement: Problem formulations from each group (or at least some examples) should be read to the class and written down on a blackboard or a projected blank transparency. Students should recognize and discuss the differences in problem statements. The instructor should help them recognize that some are better than others (and why) and that some are equally valid but just different (and why). Discuss the implications of differing perspectives, also referring to Brunner's article if students have read it. Take no more than 15 minutes for the collection of questions and the discussion.

Similarly, discuss the implications of the research questions: The specific research questions resulting from the problem formulation should be collected and written on a blackboard or a projected blank transparency (if possible such that they can be quickly related to the problem formulations collected in the previous task). Again, the instructor should help students recognize which ones really address the problem as stated, and that some are better than others (and why). Discuss at this point what kind of data would be needed to answer the specific research questions. Take no more than 10 minutes for this section.

Then have students answer the remaining questions of Activity 2.1 on the *Student Worksheet*.

C Question **C** has been prepared using the example provided on *Supporting Material 2.1* which hinted at potential problems with soil degradation data. You might elaborate on that in helping students answer this portion of the activity. You might also consider introducing students to data search on the Internet. Many important data sources are available on the world wide web. Initially this may be time consuming, but it is definitely worthwhile, given that this access venue is becoming ever more important for researchers. See the notes and some examples of such sources in the *Supporting Materials* section, *Other Supporting Aids*.

D Question **D** requires a hand-out. No example is provided, but possibilities for this exercise include a hand-out with a selection of three newspaper articles on the same subject, or a selection of a newspaper article, a personal report and a scientific article, or three paragraphs from papers by authors with very different theoretical and ideological approaches. Alternatively, compare and contrast texts that contain well-documented and not-so-well documented data, methodology and claims. Choose any topic that fits the larger purpose of your course, e.g., land degradation, deforestation, biodiversity loss, urban sprawl around a chosen city, or a local or regional issue of interest.

E Question E on the types of analyses one can undertake is an opportunity to extend the discussion to best suit the larger purpose of your class. You may not want to go into any more detail at this point of the exercise, or you may, after students have collected some ideas, want to point out the general distinction between qualitative and quantitative analysis methods and fit the students' examples into these categories. You might or might not give a prelude of the data analysis exercises that the class will do later on in this module.

F For this final step, students at this point have no actual data analysis to work with. You may demonstrate it with results and interpretations from your own research, or simply discuss the importance (and fun) of this final step in the research process.

Activity 2.2 is most effective if it follows this exercise because it allows students to summarize graphically what they just worked through step-by-step.

Activity 2.2 Getting Wired for Global Change Research

Goal

Students recall and summarize what they just worked through in Activity 2.1. They understand that research is not a linear, but at times circular, iterative, and complex process from the initial research interest to the formulation of answers and interpretations of a research problem.

Skills

✔ translating text (or otherwise provided information) into a flow diagram
✔ recalling the steps of the research process
✔ abstraction from any specific LULC research problem to the general research process

Material Requirements

Student Worksheet 2.2 (provided)
Suggested reading

Time Requirements

5 minutes (not including reading time)

Tasks

Students read Berg (1995) or obtain this kind of information from another source (another reading, or a short lecture). They should also have completed Activity 2.1 on *Student Worksheet 2.1* to be able to fill in the research process wire-diagram according to the description in that text.

The instructor should again point out the critical importance of the problem formulation step. The exercise can be done as an in-class activity or a homework assignment that probably won't take more than 5 minutes, not including time for reading Berg's chapter.

Conceptual Understanding → Problem Formulation → **Data Acquisition and Assessment** → Data Analysis → Interpretation of Results

Goal

In the second set of activities accompanying Unit 2 (Activities 2.3-2.6), students learn what LULC data are available and how to critically evaluate the quality and scope of such data. They will also understand the tentativeness of conclusions in global change research owing to the problems with the underlying data.

Learning Outcomes

After completing this set of activities associated with Unit 2, students should:

- know important factors for assessing data quality
- understand the data-related limitations of global change research
- know the difference between systematic bias, randomness and measurement error
- have a sense for what is "good" data

Choice of Activities

It is neither necessary nor feasible in most cases to complete all activities in a unit. Instead, select at least two or more from each unit, covering a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

2.3 Naming It -- Counting It: How Terminology Matters	-- analysis of FAO sources for changes in LULC terminology and measurement
2.4 Reading Between the Points ...	-- reading x/y-graphs, time series
2.5 Checking for Water-Tightness	-- discussion on data quality
2.6 Looking at the Blue Planet With Rose-Colored Glasses	-- interpreting news media for bias

Suggested Readings with Guiding Questions

The suggested readings below all treat the same subject -- problems with global change data -- but they vary in specific focus and level of difficulty (scientific jargon).

- *Background Information*, Unit 2 (provided)

  The *Background Information* in Unit 2 systematically discusses types of land use/cover and the world-wide data, estimates, and problems with these sources. Again, since the entire text may be tedious to get through for students, assign different parts to different groups in the class and help students to the heart of the material with the following questions:

  ☐ Is the glass of global change data half full or half empty?

  - ☐ What are the most important and reliable data sources for each land use/cover type discussed?
  - ☐ What can be said about the data quality of each?

- Skole, David L. 1994. Data on global land-cover change: Acquisition, assessment and analysis. In: *Changes in land use and land cover: A global perspective*, eds. W.B. Meyer & B.L. Turner II, 437-471. Cambridge: Cambridge University Press.

  A scientific text, a notch more demanding than the *Background Information* text. It contains a valuable discussion on problems dealt with in the student activities. In fact, some of the material for those activities is derived from this chapter.
  - ☐ What are some common problems with land use/cover data?
  - ☐ How is land cover/use information gathered?

- Brown, J.F. *et al.* 1993. Using multisource data in global land cover characterization: concepts, requirements, and methods. *Photogrammetric Engineering & Remote Sensing* 59, 6: 977-987.

  This article is one of many making up this special issue of *PE&RS* on *Global Change*. Depending on the emphasis of the course as a whole and students' backgrounds, several other articles from that issue might be appropriate readings. Scientific style reading. Students should have some prior knowledge of the existence and uses of remote sensing data.
  - ☐ What are the advantages and disadvantages of remotely sensed data?
  - ☐ How can data from different sources be combined to increase the land use/cover data base?

- A basic reading on sources of errors (statistics textbook) and data quality assessment at instructor's discretion

Activity 2.3 Naming It – Counting It: How Terminology Matters

Goal

Students understand the critical importance of concept definition underlying variables and measures of LULC as they frequently change and impinge on the consistency of data over time.

Skills

✓ critical reading of authoritative LULC terminology
✓ attentiveness to detail in LULC definitions and data compilation methodology
✓ group discussion and oral reporting

Material Requirements

Student Worksheet 2.3 (provided)
Access to *FAO Production Yearbooks* (alternatively, FAO reading provided in the Appendix)
Suggested or alternative readings

Time Requirements

In-class discussion time 15 minutes

Tasks

Have students first go to the library to find the indicated sections (in "Notes on Tables" in the *FAO Production Yearbooks*), let them do their comparisons and small group discussion. (Alternatively, provide them with the needed sections from the *Yearbooks* as hand-outs [the Appendix contains the respective sections]). When they return to class, or after they have had some time to study and discuss the material, hand out *Student Worksheet 2.3* and investigate the first figure. It graphically depicts what students should have found in writing in the *Yearbooks*.

Activity 2.4 Reading Between the Points ...

Goal

Students understand the concepts of sampling, interpolation, and time series of data and see their importance for the study of global change. Students should be able to critically appraise the necessity for and implications of interpolation between data points.

Skills

✓ concept comprehension
✓ reading x/y-graphs

Material Requirements

Student Worksheet 2.4 (provided)

Time Requirements

15 minutes

Task

This is a good follow-up activity to Activity 2.3 because students already understand some of the problems associated with time series of data. Go over the definitions of time series, interpolation and sampling with students and make sure they understand these concepts. To do so, you might pair students up and have them explain the concepts to each other with examples, or they should ask each other what they don't understand about the concepts. Also check that students understand that global change research constantly deals with data over time and space. This part of the activity should take no more than 5 minutes.

Then give them time to go over the next few explanations and look at the second set of graphs. Again, give students a few minutes at the outset to discuss what they do and do not understand about the graphs. Then they should mark the sample points that the left-hand graphs have in common and discuss the implications with their neighbor. The discussion takes ~ 10 minutes.

Activity 2.5 Checking for Water-Tightness

Goal

Students work together to prepare a list of issues to be aware of in data (quality) assessment. They should begin to take a critical yet realistic stance *vis-à-vis* data even if they originate from authoritative sources.

Skills

✔ brainstorming
✔ discussion
✔ critical thinking

Material Requirements

Student Worksheet 2.5 (provided)
Suggested or alternative readings (e.g., a chapter from David Kummer's published dissertation which is an engaging example of "hunting" for reliable data on deforestation in the Philippines; see the *Reference* section for Kummer [1990b]).

Time Requirements

10-15 minutes for in-class discussion

Task

After reading a selected article on issues in data assessment and the *Background Information* of Unit 2, students should brainstorm together in class and write down a checklist of all issues of which to be aware in data (quality) assessment. Give the students some hints like:

- **who collected/published the data?**
- **when** were the data collected?
- **where were the data collected?**
- **what do we know about the methodology**?
- **what do the data cover**? **what not**?
- ***how complete and consistent*** are the data?
- **for what scale are the data?**
- is the ***source reliable and up to date***?
- is it the **only source** for this type of data **[possibility of cross-checking]**? etc.

It is possible at this point in the activities that students become overly critical of data and their sources. A critical perspective is to be appreciated, but students should not throw out the baby with the bathwater. You might use examples from your own research to ground them in the reality of data availability and quality. The point students should come away with is that in research you do the best you can, including being aware of and making explicit where your data are wanting.

The activity summarizes and goes beyond what students did in Activities 2.3 and 2.4. It might also be a good preparation for Activity 4.4.

Activity 2.6 Looking at the Blue Planet With Rose-Colored Glasses

Goal

Students learn to distinguish bias and error in data and reports and understand that we all have different degrees of biases that enter into our perspectives and research.

Skills

✔ critical assessment of data (quality)
✔ discerning assumptions and bias underlying data and claims
✔ group discussion or role play: argumentation with the goal to convince an audience

Material Requirements

Newspaper, magazine and/or other articles on a chosen "hot" environmental topic

Time Requirements

15 minutes in-class discussion (more for the role play)

Task

This is an optional capstone activity that you might consider if you want to teach students about error and bias considerations on top of other data problems previously discussed. Have students collect newspaper articles on a recent, much publicized environmental "event," e.g., a devastating earthquake or tropical cyclone, or on deforestation in the Amazon, possibly even a more local issue, etc. Have them list all the data provided in these articles and discuss why they differ (e.g., because of systematic [political] bias, differences in variable definition, in measurement methodology, scale).

After they have discussed the issues for a while, point out to students (if they haven't done so already themselves) that most often you have no data to cross-check their accuracy, and even if you do, you may not easily and sometimes not at all be able to determine whether or not there are errors and biases distorting the overall picture. That's (research) life! You can only do the best you can!

This activity may be adapted as an exercise for student pairs, a small group discussion, or even, after students have some grip on the ideas conveyed here as a role play in which individual students put on a certain pair of "rose-colored glasses." The objective would be for them to try to convince a review panel of scientists (i.e., the rest of the class) of the particular position they take on the chosen issue. After letting the students find their respective positions and strategies (this could occur in a 5-minute group talk), give each student a limited amount of time to make his or her statement. Encourage them to emphasize the quality of data they have at hand to back up their position. Finish by letting the class vote on which position they found most convincing (most credible, most reliable, most "water-tight").

2 Land Use/Cover Data --

Student Worksheet 2.1 Name:

Activity 2.1 What's the problem anyway???

Until we participate in an actual research project, most of us have an unclear view of the 'nitty-gritty' of science. The data issues you read about in the *Background Information* to this unit really come into play only after we determine what it is that we want to examine. This first step is what we will focus on below. Later on in the activity, you will see how to choose the data we need for our research, and that is where you will encounter all the problems discussed in the *Background Information*.

Let's begin then by assuming that we want to know **whether there really is a relationship between human driving forces and land use/land cover change**. What do we need to know and do in order to answer this question? How do we approach this question? First of all, remember that there are four major driving forces, and there are many types of land use and land cover. So what we want to answer turns out to be a really huge question! Take a moment to think about how you would approach the problem. You may discuss this with other students in your group.

A What we are trying to do is turn a broadly stated "problem" into a "researchable" question. As a first step this requires, as you probably discovered yourself in your discussions, that we need to cut the problem down to "bite-size." On a separate piece of paper, try to re-define the problem in which we are interested in a one sentence question. Feel free to limit this question to just one of the driving forces, one or few land uses, and to a reasonable time frame (what time frame is reasonable? why?). You need to make a decision as to what is most worth knowing, most important to you! (If you can't decide right now, write down several questions that interest you). This step is called **problem formulation**.

When you are finished, exchange your sheet of paper with your neighbor, and think about what assumptions he or she must have made to write the question the way he/she did. For example, does the research question sound to you as if he or she was saying "population growth is the most forceful of all driving forces" or "natural land cover is always better than any human-altered land cover?" Give your intuition free reign! Take a few notes on a separate sheet of paper, and after a few minutes tell your neighbor what you found. Ask whether you are in the right ball park and discuss your assumptions with each other. If you can, imagine what the same kind of question might sound like under different assumptions.

B Now we have a clear question. But do we really? Say you chose to look at economic change over the past 50 years in the United States as the driving force, and you want to see if that is related to change in forestry. Your next question must be: how do you measure **economic change** or **change in forestry**? The terms in quotation marks are called *variables*, categories that in themselves are not constant but variable over time and/or space. (Other examples may be health, climate, wealth, ideology, etc.). Determining an actual measure that expresses or stands for the variable of interest is called **operationalization**. So in our example, a measure of economic change may be the change from one year to another in Gross Domestic Product (GDP), or export volume or $ of investment, etc. Change in forestry may be indicated by amount of land under all types of forest (in ha) or number of employees in the (US) Forest Service. Notice how many different measures for the same variable there can be! What difference does it make for the interpretation of your analysis which variables and measures you choose? Operationalize the variables of your research question, and choose those measures that make the most sense to you. Why did you choose the ones you did?

Variables	**Measures**	**Why this one?**
Example: Change in forestry	Total area under all types of forest (in ha) (a land *cover* variable)	Includes natural and planted forests, primary and secondary forests and woodlands

C Next, determine what kind of data you would need according to the measures you have chosen. Assume that you don't have them at hand. Where would you get them? In what form do you need the data? Do the data exist in that form, say in tables, on maps, in computerized databases? Do you need to do field work, measure something, acquire remote sensing imagery? This step of getting the data you need is called **data acquisition**. Note in the table on the next page the most important kinds of data, the form in which you would like them, and where you could acquire them.

Data Needed	Data Sources

D Now imagine that you have put in weeks of hard labor, long phone calls, spent quite a bit of money, and you finally have in front of you a pile of dusty files, maps, statistical yearbooks and more. How do you get from this pile of information to your data, not to mention the answer to your question? Notice the fine distinction between **information** and **data**. Not every bit of information you will find in this pile is actual data that you can use to answer your research question. Some of it may be outdated or may not apply to the time frame or geographic scale you chose; some of it may have nothing to do with your question. In case you want to aggregate data from different sources (a process to be done cautiously at any rate!), not all possible data may lend themselves to this compilation, and so on. The only way to find out what you can use and of what quality the data is, is through the often tedious process of **data assessment**.

We will not do a complete data assessment here (in Activity 3.3 we will come back to this). But let's focus on the difference between information and data. Use the hand-out provided by your instructor, and discuss with your neighbor what **data** you believe is pertinent to the research question that was posed along with the hand-out and what you believe is "just" **information**. Both of you should take notes on what you discuss.

E Since you did not actually collect information, we have no data to assess. But imagine you had done that, and found that most of it is of no use to you. Depending on why the information you gathered was useless to you, you might have to gather additional, better, or other data. You might even have found that your question is not answerable with the data that exist, and that you either have to generate your own data or reformulate the problem, and then go through the process all over again. For the purpose here, let's assume the "convenient" case of having enough and good-quality data for our investigation. The next logical step then is the **data analysis**. A large number of methods can be employed to analyze data, and the choice of methods depends both on the kind and quality of data and on the purpose of the analysis, i.e., the question you want answered.

Get together with your neighbor again and brainstorm about how to analyze data. For example, imagine you had the data needed for the example on the overhead that your instructor showed you: the population figures for the US for 1850 through 1990, and the numbers for wheat yield for the same years. What could you do with that? How could you use these data to answer the research question as stated? Or else, use your own research question and the list of data that you thought you needed to answer that question. How could you use those data to find your answer?

F Closely interlinked with, but for the purpose of clarity here separated from, the data analysis is the final step in answering our research question: **interpretation of the results** of our analysis. Principally, two outcomes are possible here: either we successfully were able to answer our question, or we were not and have to re-do our analysis, find more or different data, or start all over with a different question.

Since we didn't do an actual analysis, we can't interpret any specific results. But you can imagine that your research may either lead to a satisfactory answer, open up new ways to think about a problem, help you see ways to manage the problem, or it may allow you to see new connections between facts, and new relations between environmental and societal processes. All of this would be the result of your interpretation of the research results.

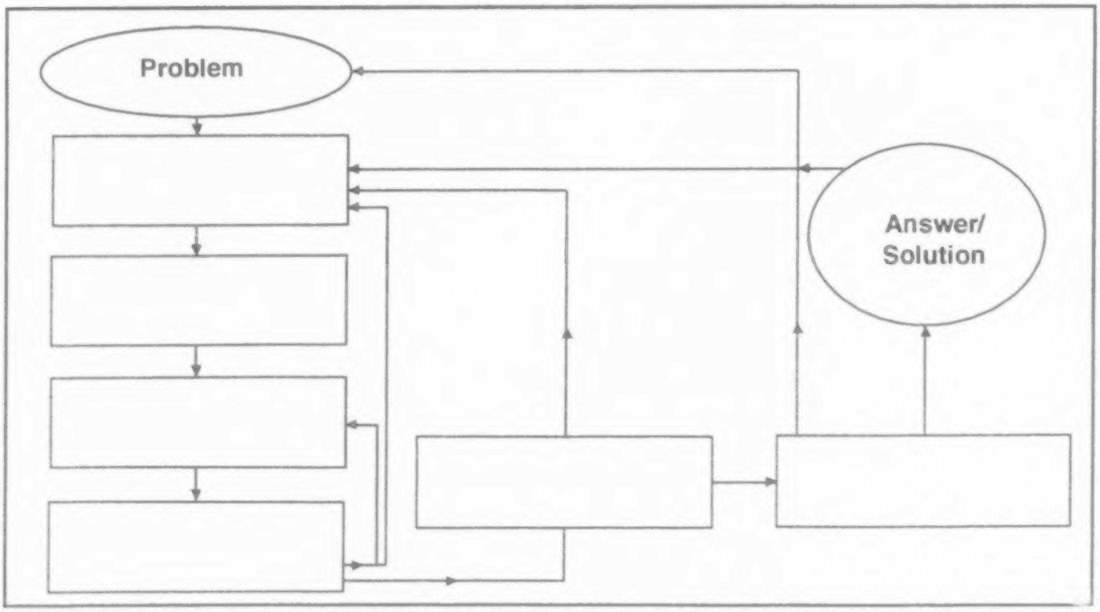
Student Worksheet 2.2 Name:

Activity 2.2 Getting Wired for Global Change Research

This "dry run" through the research process showed us at least two things. First, **problem formulation is the most crucial step in any type of research**; everything else hinges on that initial step! Your final interpretation inexorably depends on the way you asked the question and then how you operationalized the important variables, the data you sought and used after your critical assessment, and the analyses to which you subjected the data. Recall that your classmates probably stated the research question differently from you, and that their operationalization and analysis was just as reasonable as yours. But how did each one of you answer the initial problem? Even the most objective and reasonable research always contains elements of subjective judgement because of the choices we must make in the research process.

Second, it has become clear that **the research process is neither a straight nor an easy road from a problem to a solution**. Both of these points are important to keep in mind in assessing one's own and other people's research. For the flow chart below, recall each step of the research process, and fill in the blank boxes so that you end up with a logical sequence.

Figure 4: The Research Process



Student Worksheet 2.3

Activity 2.3 Naming It – Counting It: How Terminology Matters

Beginning with this activity, we take a next step in the research process, focussing on data acquisition and assessment. In other words: what data are available and how good are they?

In this activity, we will try to figure out how to identify "good" data; in a manner of speaking, data that are worth gold, not just fool's gold. We will begin by looking at land use/land cover data over time and consider how data gathered by the same researcher or agency may differ simply because the definition of the measured variable changed somewhere along the way. Recall that Skole in his paper said (Skole 1994: 442), "data from the same source may vary considerably from year to year due to changes in methodology or terminology. [As the figure on the next page shows], time series derived from later editions of the U.N. Food and Agriculture Organization (FAO) *Production Yearbooks*, an important source for this kind of [data from] recent history, differ from the same time series derived from earlier editions." Let's check that out!

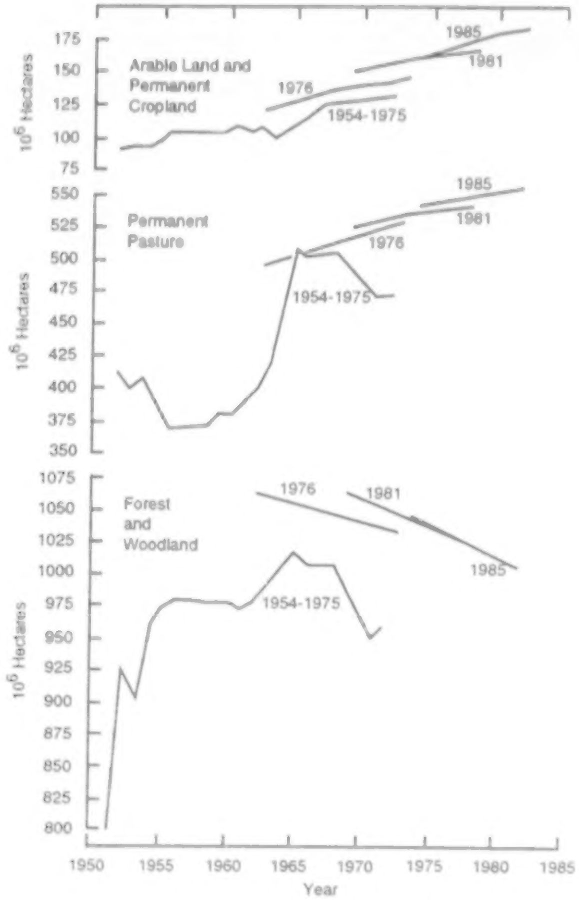
Go to your college or university library and find the *FAO Production Yearbooks*. Look up editions of 1970, 1980, and 1990 (or use the hand-outs provided by your instructor), and note the definitions used for **arable land, permanent cropland, permanent pasture**, and **forest land**. Take notes on what you find. Are there any differences in the definitions? If so, do you feel they matter?

Next, find any description for how the data on these categories were obtained, what they include and what not, to what time span they refer, and how the methodologies to aggregate or obtain the data in the first place differ from decade to decade? Take notes on all of this or make yourself copies of the relevant pages. Then meet in small groups (of three or four) and compare and discuss what you found in the *Yearbooks*. You should think about the following questions:

- What do these differences mean for the quality of your data set?
- Given these data, how confident are you about the *actual* change in land cover shown in this figure?
- If you were to cautiously interpret these time series, what could you say?

Take notes on your discussion and report your findings in a short oral summary the next time your class meets.

Figure 5: Differences in the Data on Various Land Uses from the FAO



Source: Skole, D. 1994. Reproduced with the permission of Cambridge University Press.

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Student Worksheet 2.4

Activity 2.4 Reading Between the Points ...

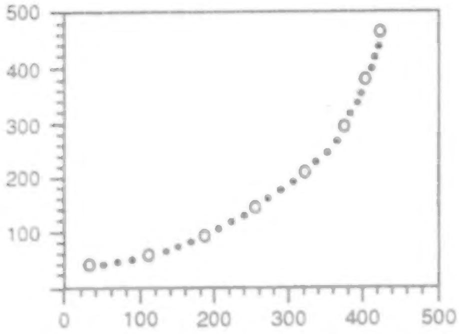
Now we will look at time series, interpolation, and sampling. Almost all global change research involves looking at processes over time. This means that we have to see

✔ whether data are available for the time span that we are interested in,
✔ what their quality (completeness, consistency, comparability, etc.) is, and
✔ which of the data to use in case there are more data than we can feasibly include in our analysis.

Let's begin by defining the concepts of time series, interpolation and sampling:

> A **time series**, as the term implies, is a sequence of chronologically ordered data values. For example, if you measured the outside temperature every day and ordered the measurements by date, you would have a time series of temperature data.
>
> **Interpolation** is a method employed for estimating values in between sample points. Paraphrasing the common idiom, interpolation can be thought of as "reading between the points." Usually, you would do that by following the trend that the existing sample points suggest or by relying on a pattern that you expect to underlie their distribution. The following graph shows this:

Figure 6: Interpolation Between Sample Points



Sampling is the process of selecting your objects for analysis from a potentially infinite number of objects with similar characteristics (called a population). Since not all members of a population can be incorporated in the analysis, especially when the population is very big, a specific (purposeful) or random (representative, bias-free) portion of it needs to be drawn to obtain clues about the entire population. Sampling schemes determine the way in which this portion is obtained. For example, one could conduct a survey of American farmers to obtain data on their land use practices, but because there are thousands of farmers (the population), we decide to survey only a subset of them (a sample of maybe 250) drawn randomly from addresses available from farm bureaus in different regions of the country (the sampling scheme).

Now let's apply these concepts to land use and land cover. When you look at the graphs on the next page, you'll see three graphs of **area of cultivated land over time** on the left, and three of **carbon flux over time** on the right. Don't worry about the meaning of "carbon flux" for the moment; all you need to know right now is that on the horizontal (x-) axes you have **time**, and on the vertical (y-) axes you have **some quantity**. The graphs on the left each have three points in common which have identical x and y values. The three different lines show three possible interpolations from the same small sample of points. Once you feel comfortable with these graphs, find and mark three sample points that all three graphs on the left hand side have in common.

What does this have to do with land use change? Read the little box of information on the right and then go on with this exercise.

Since the **change in carbon storage in vegetation** (i.e., carbon flux) is predicted from the **change in the area under cultivation** through a mathematical formula (called a model), the three graphs on the right show the three predictions that resulted from these data points and the interpolation between them. In short, "[s]parse sampling in space and time can result in a variety of interpolations from a single data set" (Skole 1994: 442).

Carbon is one of the most common chemical elements on earth. It can be found in the earth's atmosphere as CO and CO_2 and as one of the most essential components of organic materials (e.g., in plant or animal tissue). When this material dies off and decays (or burns), the solid carbon compounds are released as gaseous carbon compounds to the atmosphere. The invisible, odorless gas CO_2 is very significant in this respect because it has the capacity to let solar radiation into the atmosphere, but not back out. It "traps" heat like a greenhouse. Hence the term "greenhouse effect" -- a natural phenomenon that is enhanced by human-induced releases of CO_2 and other radiatively active gases.

Now pair up with a classmate and discuss the following questions:

- So what? Why should we be concerned about sampling, interpolation, and a small number of values? After all, the fewer values, the less calculating I have to do ...
- What would have to be done in order to avoid this problem with few sample points and interpolation for modeling and interpretation? Or: how does the data set have to be improved?

Take notes on your answers and report and discuss them later in class.

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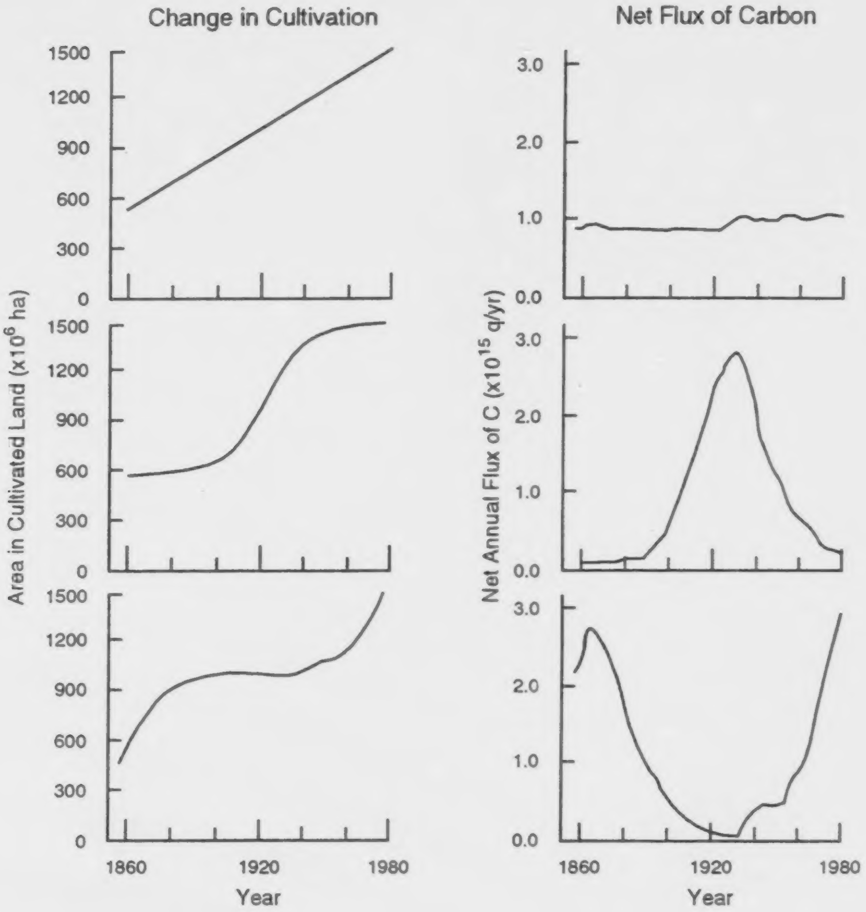
Figure 7: Three Interpolations Between Data Points & Resulting CO_2-Flux Models



Change in Cultivation

Net Flux of Carbon

Source: Skole, D. 1995. "Data on land use change: Acquisition, assessment, and analysis." In: *Changes in land use/land cover: A global perspective*, eds. Meyer, W.B. and B.L. Turner, 444. Reproduced with the permission of Cambridge University Press.

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Student Worksheet 2.5 Name:

Activity 2.5 Checking for Water-Tightness

Brainstorm in class what makes "good data." What do you need to ask about the data to assure yourself of their adequate quality (meaning suitable and satisfactory for your intended purpose)? What do you need to check? Compile a checklist of things to consider in data assessment as you go.

You may refer back to this list in later exercises and to assess other research articles and the data used in them.

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Student Worksheet 2.6

Activity 2.6 Looking at the Blue Planet With Rose-Colored Glasses

In this final activity of Unit 2, let's look at the difference between bias and error in data and reports and see how these biases and errors enter into them. In fact, you will find that everyone's world view is to some degree biased. The important thing is to become aware of this and to take it into account in what we or others write and research.

Collect newspaper articles on a recent, much publicized environmental "event," some hot topic that you are interested in, e.g., a devastating earthquake or tropical cyclone, or deforestation in the Amazon or possibly a more local issue. Make a list of all the data provided in each of the articles (e.g., number of deaths, injured people, amount of damage to houses etc., degree of destruction, degree of threat) and discuss when you get back to class why they differ (e.g., because of systematic [political] bias, differences in variable definition, in measurement methodology, scale). To facilitate your overview, you may list these data in form of a table.

Article/Event	Source	Deaths	Injuries	Damage	Threat	etc.....		

Under what circumstances do you think you would be able to recognize the errors and biases in this kind of data? What circumstances would prevent you from recognizing them?

You may decide to do this activity as a role-playing exercise in which you put on a pair of "rose-colored glasses," i.e., you play someone with a perspective that is slanted in a certain way. For example, you could be the token environmentalist, or corporate executive, or government official. The objective would be for you to try to convince a review panel of scientists (i.e., the rest of the class) of the particular position you take on a chosen issue. Determine your position and develop strategies to convince the panel. (You could do this in a five-minute strategy session with some of the other students.) You will then have a limited amount of time to make your statement to the panel. Emphasize the quality of the data you have on hand to back up your position. After you have all had a chance to make your statements, the panel (class) will vote on which position they found most convincing (most credible, most reliable, most "water-tight").

2 Land Use/Cover Data –

Answers to Activities

Activity 2.1 What's the Problem Anyway???

A This first exercise is a logical continuation of the activities students did previously in Unit 1. The small group discussion allows students to incorporate newly acquired knowledge into their existing knowledge of global change and land use issues, and to paraphrase the problem in their own words and thus manifest the subject matter as solid understanding. By allowing them to formulate their own problem statements and more narrow research questions, students should be encouraged to focus on what **they** find most interesting. This is important to engage students' interest and motivation for the following exercises.

As you go from group to group, help students frame the issue; ask them **what they want to know about it, and why that would be interesting** to know. Once they clarify their own interest, specific problem formulation is much easier.

Depending on your own research interests, choose a small and clear example of narrowing a broad area of interest down into one or two research questions. Alternatively, use *Supporting Material 2.1* over the course of this activity, walking students step by step through the overhead. Students will understand the task more easily after you demonstrate the process.

Give students some time to formulate problem statements and specific research questions in small groups or pairs. Then display students' problem formulations and research questions on an overhead transparency. In order to help them see which problem formulations are better than others, you may use your own approach or point out and discuss at a minimum the following issues:

- Are the statements clear/confusing?
- What are the important concepts in this problem? What data do we need to get?
- Is the place, time (span), geographic scale, the researched population etc. specified?
- If you were to undertake the research on this problem, would you know what to do? (And so on...)

If any of these statements reveal areas in need of improvement, reformulate it with students' help right on the transparency.

Also discuss how, depending on one's perspective (paradigm, underlying theory, etc. -- if this language is appropriate for your students), a problem may be researched in more than one way, partially because the problem is stated in different ways, but also because what is acceptable evidence and methodology may differ.

B The operationalization is, again, demonstrated on *Supporting Material 2.1*. Be flexible in allowing answers but ask students why they chose a particular measure for a given variable.

C Discuss with students exactly what kind of data they would have to collect in order to answer the research question as stated. The example on *Supporting Material 2.1* hints at some of the problems that can be expected. Are these data available? Where, from whom? Is there more than one way (there is!) to operationalize the chosen variables? How would the data search, the data analysis, and the likely results differ if other variables, other measures were chosen? Which measures seem more appropriate than others? What do these measures cover, what do they leave out? Thus, how limited or applicable are the likely answers we will find?

With questions like the above, students will gain a sense for the importance and the lasting implications of the problem and research question formulation. Splitting up this complex task in several steps as is done on *Student Worksheet 2.1* will further help them clarify the process.

Here is an additional example besides the one provided to students on the *Student Worksheet:*

Problem: Has population growth driven (i.e., caused) deforestation in the Brazilian Amazon over the past 50 years? **(Note: This question implies nothing about the strength or importance of this driving force. In the interpretation of results, this should be assessed.)**

Variables	**Measures**	**Why this one?**
Deforestation	total area cleared	obvious choice; does not include reforestation or regrowth
Population growth	number of births - number of deaths over the study period	common measure

Data needed/Source?
Remote sensing data for Brazil / NOAA or similar sources
Birth and death rates for Brazil / UN Demographic Yearbook

You might have to assist students in thinking of data sources, or else let them do some research of their own in the library or on the Internet (see *Supporting Materials*). Note the **limitations of these data** with the students (remote sensing in tropical areas (clouds); regrowth after clearing is very similar in reflectance values to older growth forest; boundary recognition on remote sensing imagery; demographic units are not necessarily the same as ecological region, etc.).

D Reinforce the distinction between data and information provided on the *Student Worksheet*. The specific results of this activity depend on the hand-out you will put together for students. Point out to students that data and information are sometimes hard to distinguish. All data are information, but not all information is data.

Information is -- broadly defined -- any sensory detail that contains meaning. It may or may not be relevant to the issue we would like to research. And it may or may not be direct input into our analysis. When we undertake qualitative research the distinction between data and information becomes rather blurry. Often times, information gives us clues to the background or context of the researched problem.

Data is that specific portion of information that directly enters into our analysis. It may be quantitative or qualitative, but it is always specific to what we need for the analysis.

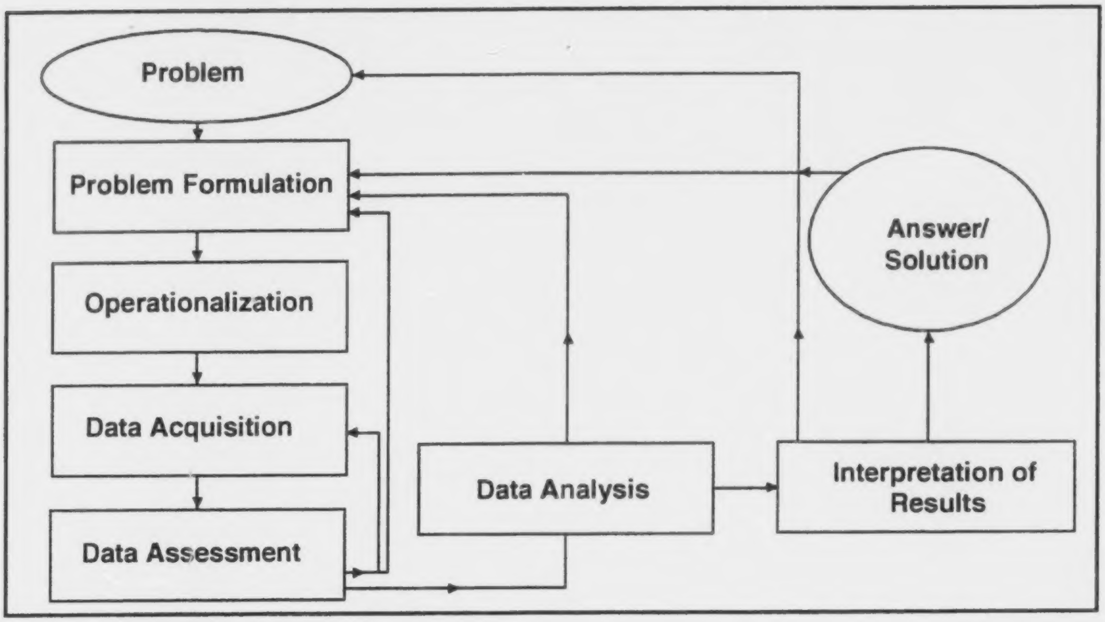
E You might have to jump start the brainstorming process by giving students an example of your own research or by referring to *Supporting Material 2.1.* Unless this module is taught in a research methods class, it's not so important for students to have this technical/statistical/ research know-how, but to think logically and creatively through the research process.

F You might demonstrate this again with an example from your own research; otherwise no specific instructions here.

Activity 2.2 Getting Wired for Global Change Research

The completed flow chart will look like Figure 8 on the following page. Repeat the steps, following the arrows (and the various pathways shown), if students have trouble filling in the boxes.

Figure 8: The Research Process (Answer)



Activity 2.3 Naming It – Counting It: How Terminology Matters

Students' findings will include definitions and notes from the three *Yearbooks* listed below. Their discussions should result in an awareness of small details and that the definitions indicated inconsistencies, variability, and subjective judgements on the part of those collecting data in the reporting countries and those compiling the FAO *Production Yearbooks*. Furthermore, students should develop a healthy scepticism for data (no matter from what source they come), without loosing faith in the worthiness of scientific investigation.

FAO Production Yearbook 1970

Definitions:

Arable land: Land under temporary crops (double cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle. Within the scope of this definition there may be wide variations among reporting countries; the dividing line between temporary and permanent meadows, for instance, is rather indefinite; the period of time during which the unplanted land is considered fallow varies widely.

Land under permanent crops: Land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee and rubber; it includes land under shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber. A problem arises here as to whether bamboo, wattle, or cork oak plantations should be included under this heading or under forest land. Data changes are due to actual changes in land use categories (esp. in Europe and North America) and improvement in statistics (esp. from other continents).

Permanent meadows and pastures: Land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). Permanent meadows and pastures on which scattered trees and shrubs are grown should also be included in this category, although some reporting countries include them under forests.

Forest land: Land under natural or planted stands of trees, whether productive or not. It includes land from which forests have been cleared but that will be reforested in the foreseeable future. The question of savanna raises the same problem as mentioned (under **permanent meadows and pastures**).

Notes:

- Crop areas generally refer to harvested areas, with exceptions: tea, sugarcane, cereals -- sown area; grapes, abaca, agaves, hard fibers -- planted area.
- Continental, regional and national totals shown for most agricultural items, but world not covered evenly or completely because of paucity of available data.
- Production of crops is reported by countries by calender year, agricultural years, marketing years. These are then allocated according to the calender year in which the entire or the bulk of the harvest occurred. Most figures refer to the calender year, with few indicated exceptions. Livestock numbers per 12 month period ending Sept. 30.
- Some countries are not shown in the tables, but included in the totals. Explanation: very rough estimates, only reliable to the order of magnitude, thus good enough to adjust the total but too rough as a country estimate. In some cases, estimated adjustments to make up for deficient geographical coverage of the country.
- Changes in country boundaries, or FAO classifications of regions are indicated separately in country notes.
- Any other additional information in footnotes beneath tables, or at the end of the volume.

FAO Production Yearbook 1980

Definitions:

Arable land: First sentence is the same as in the 1970 yearbook. Large shifts in African countries due to the exclusion of what is considered fallow land resulting from shifting cultivation.

Land under permanent crops: First sentence same as in the 1970 yearbook. No mention of second or third sentence anymore.

Permanent meadows and pastures: First sentence same as in the 1970 yearbook. No mention of second sentence anymore.

Forest land: Includes forest and woodland, i.e. land under natural or planted stands of trees, whether productive or not, and includes land from which forests have been cleared but that will be reforested in the foreseeable future. No mention of second sentence from 1970 yearbook anymore.

- Specific deviations from the definitions, measurements, aggregation etc. in selected countries are listed by type of crop and country if necessary.

Changes/Additions to notes in *FAO Production Yearbook* 1970:

- Crop areas mostly refer to harvested areas, but some exceptions refer to planted areas.
- Data on yields of permanent crops are not as reliable as yields of temporary crops.
- "When considering the section on land use it should be borne in mind that definitions used by reporting countries vary considerably and items classified under the same category often relate to greatly differing kinds of land.

FAO Production Yearbook 1990*

Definitions (changes since 1980):

Arable land: Just the wording is different: "abandoned land resulting from shifting cultivation is not included in this category."

Land under permanent crops: Same as before.

Permanent meadows and pastures: Same as before.

Forest land: Same as before.

Notes (changes since 1980):

- Figures from individual countries may not add up to the totals given for the entire table due to independent rounding of country totals or of overall totals.
- New note with cereals: difference between sown and harvested land is negligible in normal years (but not so in drought or other bad years)
- For specific crops there are minor changes that reflect changes in agriculture in general, e.g., mixed cereals or buckwheat are not individually listed anymore, but they still figure into the totals of cereals.
- Livestock numbers refer to calendar years with few exceptions.

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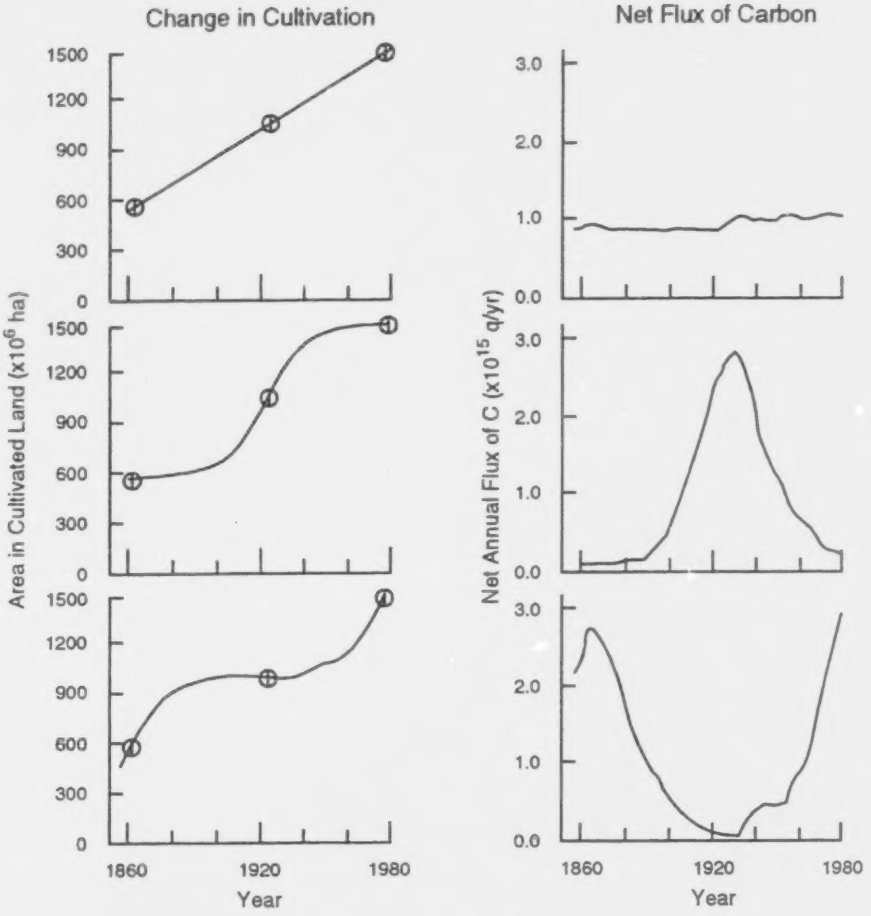
* At the time of the publication of this module, the 1990 volume of the *FAO Production Yearbook* was not available. Since the point of the exercise is to pay attention to small details and finding differences between publication years, rather than what exactly the 1990 Yearbook said, the "Notes on Tables" of the 1991 FAO *Production Yearbook* have been included in the Appendix.

Activity 2.4 Reading Between the Points ...

Make sure students understand the concepts of time series, interpolation and sampling. You might pair them up and have students explain the terms to each other (no more than 5 minutes). Clarify the questions that remain after that process. The sample points that the three graphs on the left have in common are marked in the graph on the next page.

Figure 9: Three Interpolations Between Data Points and Resulting CO2-Flux Models (Answer)



Source: based on Skole, D. 1995. "Data on land use change: Acquisition, assessment, and analysis." In: *Changes in land use/land cover: A global perspective*, eds. Meyer, W.B. and B.L. Turner, 444. Reproduced with the permission of Cambridge University Press.

The kinds of answers to look for in students' discussions on the implications of sparse sampling would include:

- most importantly: increase the sampling density (get more data!);
- cross-check with data from other sources; if they are compatible, fill in the holes.

Activity 2.5 Checking for Water-Tightness

The task description for instructors already contains a list of things that students should come up with. Jump start their thinking with some examples from that list, or else describe a hypothetical situation of data you might have and ask students to find out how good they are. If you would like to expand on the importance of data assessment, David Kummer's dissertation (cited in the reference list of the *Background Information*) is a wonderful example of an excruciating data search and assessment with respect to who cuts down how much rainforest in the Philippines.

Activity 2.6 Looking at the Blue Planet Through Rose-Colored Glasses

Bias and **error** are two concepts that are not always easily distinguished. Intentionality is not a sufficient condition to distinguish them since we all approach "reality" from a certain perspective that can be interpreted as a form of bias. Take sufficient time for students to understand this basic point. Use examples from their daily life experiences to understand "bias."

Then explain to them the term "error" and let them name a few sources of errors (e.g., measurement instrument broke down, data were lost, etc.); you may want to include the notion of "random error," which represents the natural variability in the occurrence of a phenomenon. Note the difference between a measurement instrument that is occasionally out of order (>> error) and a measurement instrument that is badly calibrated (>> systematic error).

Use the collection of newspaper articles that students gathered to manifest the distinction between the two. If students can't decide whether it's bias or error that they are confronted with, let them discuss the arguments for either case with each other. Help them ask the kind of questions that will allow them to make the distinction. Find consensus. Also make sure to point out, that sometimes we just can't tell. We certainly do not always know whether data contain error or bias or not!

3

Relationships Between Land Use/Cover and Macro-Forces of Change -- Background Information

Introduction

The 1990 SSRC land use report details some of the issues involved in determining the human causes of land use/cover change. Foremost among these are the "untested" claims that certain macro-forces are the global-scale, underlying causes of environmental change in general. Taken at their base or rudimentary claims, then, such forces should be statistically related to land use change at a global scale. The failure to find such relationships, of course, does not prove that the candidate macro-forces are not such, but it may signal that the proposed relationships are much more complex than the general arguments for them and that context involves many mediating variables that influence land use change. We cannot resolve these issues here, in part because of the data problems articulated in the sections above.

Relationships between LULC and the driving forces of change

Untested claims about the causes of global environmental change

Complex relationships

Instead, we begin at the beginning, so to speak, and search for simple, direct links between certain candidate forces of change and certain land use changes at a global scale. Specifically, we ask how important are population, technology, and economic development in transforming certain land use/covers: cultivation, forest conversion, and livestock. To answer this question, we take each of the land use/covers separately and see how change in the area under, for example, cultivation is related to change in population, annual energy consumption, and Gross Domestic Product.

Analysis

The data used in this analysis are those drawn from the sources described under each LULC section in Unit 2. The human driving forces or independent variables are the change in population size (population force), total annual energy consumption (a surrogate for technological capacity), and gross domestic product (GDP) -- a surrogate for the level of economic development. The land use changes or the dependent variables are area in cultivation (permanent crops only), forest (total area in forest), and livestock numbers and pasture land. These data were taken from *FAO Production*

Independent variables:
- **Change in population**
- **Annual energy consumption**
- **Gross domestic product**

Dependent variables:
- **Area in cultivation**
- **Forest cover**
- **Livestock numbers**
- **Pasture land**

Yearbooks (land use and population) and the *UN Statistical Yearbook* (GDP and energy). The data were examined both spatially and temporally (1961-65 to 1985).

Our global-scale temporal analyses consisted of simple regressions of the dependent variables of land use/covers against the independent variables of the driving-force indicators for the time period of 1961-65 (average) to 1985. The intent was to determine if global relationships can be detected, e.g., whether population growth is associated with a loss of forest cover, and then see if we find similar relationships at the regional scale. Our spatial analyses involved regression of the same set of variables but through the optic of their percent change over time (% change of land-use divided by % change in driving forces indicators) by regional aggregates and for 36 countries. We aimed at representing all continents, a range of environments, forms of government, population densities, and levels of economic development. The percent changes were from the time period 1980-1985. The goal was to determine if relationships between the forces of change and the types of LULC change are related at the global scale.

Results

Results of the analysis

Global findings

At the global level for the time between 1961-65 (average) and 1985, we found strong and significant correlations between each independent variable (population, energy consumption, and GDP) and three dependent variables (cultivation [permanent crops], forest, and livestock numbers).[14] As expected at this scale, forest cover is negatively related to the independent variables: as population, energy consumption, or GDP increases, forests decrease. For permanent crops and livestock numbers, there is a positive relationship: as the independent variables increase so does livestock and permanent cropland. Interestingly, compared to the above land covers, the amount of permanent pasture showed weaker, but significant, positive correlations with the independent variables. Such global average relationships, however, do not necessarily hold for regions. For example, in Europe and in Asia, the relationship between population increase and amount of forest cover has been positive: forest (area under tree cover) has increased as population has grown. In the developed world, as population increased, permanent pasture and livestock numbers decreased; in developing countries permanent pasture and livestock increased, yet in centrally planned economies, permanent pasture increased but livestock decreased. Thus, analysis at the regional level reveals numerous inconsistencies with the relationships found at the global level.

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[14] The correlation coefficients (r^2's) for land uses versus population, energy consumption, and GDP, respectively, between 1961-65 and 1985 are: forest loss (negative .766, .646, .787); permanent crops (positive .905, .979, .869); permanent pasture (positive .435, .591, .352); all domesticated animals (positive .989, .934, .927). When forest is run against the variables for 1970 to 1985 the correlation coefficients are negative .956, .997, .970, respectively.

Global vs. regional relationships

To explore this regional diversity in more detail, 36 countries (representing an array of political, economic, and environmental conditions) were selected for analysis of these relationships at the scale of nations. We found no strong or significant correlations between the percent change in the driving forces variables and the percent change in land uses from 1980-1985 on a regional comparative basis.[15] The same was true when the regions were grouped into three categories, representing the so-called First, Second, and Third Worlds. Between 1980 and 1985, population density and energy consumption increased in all regions, but a corresponding decrease in forest cover was not found everywhere. In the Americas, Africa, and both the developed and developing worlds, forest cover decreased. In Europe, Asia, and the centrally planned economies (Second World), forest cover increased!

Regional diversity

Preliminary Interpretations

Interpretation of results

Turner and Meyer (1991) outline some of the problems related to data and methodology that may mask the proposed relationships between human driving forces and global land use/cover changes, and restrain the kinds of analyses that we have undertaken here. Paramount among these is that the spatial units for which data exist on the independent variables (e.g., population growth) do not match the spatial units for which data are collected on land use/cover change. For example, energy consumption data may be collected for economic sectors or entire regions, while data on, say, land under

Mismatch of spatial units

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[15] For the percent change in population compared to the percent change in the land uses for the 36 countries, correlation coefficients (r^2's) between 0.000 to 0.085 were generated.

cultivation may be collected per nation.

This mismatch between spatial measurement units also afflicts studies that do show statistical correlations for macro-driving forces and land use change. For example, Rudel's (1989) recent demonstration of such a relationship between population increase and deforestation in the tropical forest realm of the world weighs country-wide population increases against more localized deforestation data. We must remember, however, that population increases can take place anywhere, especially in urban areas, while deforestation takes place only where there are forests, so who is to say that nation-wide population increase caused deforestation in a few regions of a country? When we do find correlations between driving forces and land use/cover changes, it is tempting to forget all the data problems and let our beliefs in certain macro-driving forces color our view of the processes that give rise to land use and cover change. These changes are, however, largely cumulative in nature, i.e., they are the sum of many interacting processes (Turner *et al.* 1990).

LULCs result from many interacting forces

Our results, therefore, should be viewed cautiously. The global aggregate correlations may well be on target, but their importance for understanding global change must be weighed in light of the forces of change that were not tested here. In other words, to claim that population growth or economic growth drives a particular land use/cover change is only tenable if we can say with certainty that other forces were not involved (or at least negligible). The three driving forces examined here more-or-less capture the kinds of forces that drive consumption and production. It is largely a truism to demonstrate that land use change follows from increases in them, given sufficient time. More important to our understanding would be to demonstrate that these kinds of forces were correlated, but others, such as political culture, were not. Such a finding would signify that the production-consumption forces are more fundamental to land use change than the social organizations in which they operate. Unfortunately, land use/cover change research cannot make any assessment of this proposition at this time.

The regional comparative correlations may also be on target, and do not necessarily contradict the global aggregate patterns. The latter are, after all, averages, created by a range of relationships that differ across space. This variation is more important than seems to be recognized, because it indicates that a proposed macro-force changes its relationships with land use changes as the conditions in question vary. Until these differing relationships are thoroughly assessed and worked out for individual regions, we cannot claim that the social, political, and cultural conditions (i.e., the context in which macro-driving forces act) matter, and how exactly they influence any macro-force or the interactions among them. It should be pointed out here that pan-regional or -national demonstrations of relationships between proposed macro-forces and certain kinds of land use/cover change have almost invariably focused on regions that were similar with respect to either environmental or economic conditions (e.g., humid tropical, Third World countries; see Rudel 1989).

Conclusions

Conclusions

Earlier we stated the major questions that global change researchers struggle with:

☞ Focus of this module

- What forces drive land use/land cover change?
- What impacts -- direct and indirect, now and in the future -- do these changes have on the environment and on human society?
- Does society need to respond to these changes, and if so, how, and how well is it able to do so?

The foregoing discussion has mostly focussed on the first of these very complex and difficult questions. In the first Unit of this module, we looked in a very general, conceptual sense at how land use relates to global environmental change. In the second Unit, we looked at the data available for the study of this mutual relationship between land use and land cover on the one hand and driving forces on the other. In and of themselves, the data -- or the lack and questionable quality thereof -- are a major impediment to our better understanding of the causes of global environmental change manifest in land use/land cover.

Data are just part of the story

Scale dependence

The data, however, are just part of the story. Similarly fundamental is the lack of a theoretical foundation that adequately captures the dynamics between land use change and human driving forces at **different** scales and **between scales**. This shortcoming is clearly evident from the correlation analyses and the discussion of the results here. Leaving the data problems aside for the moment, these analyses show that whether or not we find a relationship between two variables also depends on scale and the **specific regional**

contexts of the land uses and driving forces in question. There is no **single answer** to "what driving forces cause what land use/cover change and how much of it?".

Context matters!

There is no single answer to what causes land use/land cover change

Clearly, the fundamental issues in answering just the first of the three questions stated above severely limits our ability even to begin to answer the other two. Yet those are the questions to which most of us -- the John and Sally Smiths of the world, and policy makers in particular -- want answers. What will happen to us? And what can we do about it? "Good" answers to these questions need to include good data and a good understanding of the fundamental causal linkages, yet, in a different sense, "good" answers might be those given soon, simply because we might have to act soon in order to mitigate or even prevent some of the impacts that are likely to occur.

What are "good" answers to these questions?

A dilemma for everyone

The dilemma that results is a dilemma for everyone: it is a dilemma for scientists who do not want to compromise on the quality of research, yet who are in a position to recognize and examine potential dangers; for policy makers, who are under political pressure to act on what is perceived as a threat to health, well-being or even survival by some, and to economic welfare and profit by others; and for every lay person who must choose between believing either the "alarmist, red-flag wavers" or the "wait-and-see, thumbs-up optimists" camp, and then draw their own conclusions on whether or not to change their behavior. After all, some of these changes are supposed to occur only in the distant future and in far-away places. For each one of them it would be easier to turn a blind eye to the issues of environmental change than to confront these global, enormously complex, often hidden, and politically charged problems that -- depending on the pace of global change vs. that of our scientific progress -- might challenge us beyond our capacity to fully comprehend and adequately respond to them.

High stakes

What stops us from turning that blind eye, however, is that we have high stakes in the issue of global change: we have face and political clout to lose, we have our investments to lose, we have human health and environmental assets to lose, in fact, we have people to lose ... or rather, I have the cropland to lose on which I depend for food, I risk losing the water that I need for survival, I risk losing my favorite beach to sea-level rise and coastal erosion, my farm can go bankrupt, I can lose my job, the forest I like to go for walks in might be clear-cut.

And while I -- here in the rich First World -- have many things to lose that I value, there are other people on this earth who will suffer less, maybe even gain, from global environmental change, and many, many more in the Third World who will suffer a great deal more than I. We all need to think of our personal share in causing global environmental change (or, more specific to this module, land use/cover change), and our personal responsibility in responding to it. It appears as if our ability to affect the environment on a global scale has skyrocketed while the evolution of a similarly far-reaching global ethic continues to lag behind.

Our immense scientific concern with global change and the heated debates from international forums to parliamentary floors to backyard parties over whether or not there are dangers involved, and for whom, are but the most audible indication of the fact that global change -- ultimately -- is a personal matter: it is about the ethical decisions each one of us does or doesn't make, the behaviors of consumption and reproduction each one of us does or doesn't reconsider and maybe change, and the benefits and burdens each one of us will experience in an ecological and human environment that tomorrow might not look anything like what we see outside our window today.

Global change is a personal matter

3

Relationships Between Land Use/Cover and Macro-Forces of Change -- Instructor's Guide to Activities

Conceptual Understanding ⇨ Problem Formulation ⇨ Data Acquisition and Assessment ⇨ **Data Analysis** ⇨ **Interpretation of Results**

Goal

In this first set of activities accompanying Unit 3, students learn to use some basic bivariate statistical tools in order to assess relationships between human driving forces and LULC change. They also learn to interpret the results of data analysis carefully and cautiously.

Learning Outcomes

After completing the first set of activities associated with Unit 3, students should:

- understand the difference between association and causality between two variables;
- be able to "read" a scatterplot and a regression line;
- know how to calculate a regression model from tabular data (optional);
- be aware of the care and caution necessary in interpreting data and data analysis results;
- be able to relate the data analysis results back to the larger research question at hand; and
- have a sense for the enormity of global change research, and the tentativeness of knowledge we currently have about the HDGC.

Choice of Activities

It is neither necessary nor feasible in most cases to complete all activities in a unit. Instead, select at least two or more from each unit, covering a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

3.1 Finding Order in Chaos: Scatterplots	-- Understanding scatterplots, correlations
3.2 Feeding the Millions	-- Constructing scatterplots
3.3 What Depends on What in Land Use Change?	-- Simple regression analysis
3.4 Land Use Change and Driving Forces at Different Scales	-- Regression analysis and interpretation
3.5 Film: *Banking on Disaster*	-- Critical film interpretation and discussion

Suggested Reading with Guiding Questions:

The readings suggested for this activity include a reading on the statistics material, Unit 3's *Background Information* that exemplifies the type of analysis discussed here, and a research article that is a good example of a careful analysis of land use/cover change. Choose the readings most appropriate for the students in your class.

- *Background Information*, Units 2 (partial) & 3 (provided)

  If students have read up on or heard about some basic statistics, this will be an easy read. Otherwise guide them through Unit 3 in conjunction with the exercises described below.

  ☐ What can be said about the relationship between the three major human driving forces and LULC change in general?

  ☐ Can the relationships be seen at the global and the regional scale? What's the difference? Why?

- A simple introductory chapter on bivariate graphic depictions, correlation, and regression at instructor's discretion (e.g., Earickson, Robert, and Harlin. [1994]. *Geographic measurement and quantitative analysis*. Macmillan College Publishing Company: New York; chapter 8 "Bivariate correlation and linear regression")

  Choose a text that is appropriate for the skills level of your students that also meets the needs of your course. Earickson *et al.* is very accessible if read from cover to cover. Students will need help if they have not had any statistics.

  ☐ What is correlation?

  ☐ What is regression?

  ☐ What is the difference between the two?

  ☐ What can be said about causal relationships when looking at a scatterplot or regression line?

- Rudel, Thomas K. 1989. Population, development, and tropical deforestation: A cross-national study. *Rural Sociology* 54, 3: 327-338 (provided).

  A careful, readable research article that tests a number of "common hypotheses" -- interesting for students who might have preconceived notions about deforestation or who don't know much about it at all but want a balanced view. (See also the comments on this article in the *Background Information* of Unit 3.)

  ☐ What measures does Rudel use in his analyses?

  ☐ What are the findings?

Activity 3.1 Finding Order in Chaos: Scatterplots

Goal

Students learn the basics of plotting data in a coordinate system (tabular data to scatterplot) and understand the concept of correlation between two variables. At the end of the activity, students should know the rules of thumb of when data are positively, negatively, or not at all correlated.

Skills

✔ reading scatterplots and coordinate systems
✔ plotting data in a coordinate system
✔ abstract and analytical thinking

Material Requirements

Student Worksheet 3.1 (provided)

Time Requirements

10 minutes

Tasks

Instructors help students interpret the first two scatterplots on *Student Worksheet 3.1*. (What does each data point mean? What is measured along the x-, what along the y-axis? etc.) Then let students go through the next two scatterplots. Give them time to think through and discuss the questions with their neighbors, and write down some answers to the first two questions. Make sure they understood the concept of correlation, and stress the fundamental difference between association and causality.

Then let them find the correct "rules of thumb" for **no correlation, positive correlation** and **negative correlation**. Students learn to distinguish between these by using the next two scatterplots provided on *Student Worksheet 3.1* After they have taken some notes, discuss the correct answers in class and then introduce the concept of a **linear relationship** between two variables. (As the data values of one variable increase, what happens to the other variables' values? How fast is the concurrent increase or decrease?)

Activity 3.2 Feeding the Millions

Goal

Students plot data in a coordinate system with linear and logarithmic scales and draw a regression line through the data cloud. The principle behind regression is explained.

Skills

- ✔ plotting data in a scatterplot
- ✔ analytical thinking
- ✔ interpreting population vs. cropland data

Material Requirements

Student Worksheet 3.2 (provided)
Suggested or alternative reading on correlation, linear relationships and regression

Time Requirements

15 minutes

Task

This activity is more easily done after students have understood the basics of scatterplots taught in Activity 3.1. Have students plot the population vs. cropland per capita data in the semi-log graph provided. If students are not very familiar with plotting on the semi-log graph paper, have them do that in pairs, i.e., discuss the task with their neighbor and then each plot the data. Assist them to the extent you deem necessary. Especially help students understand the concept of a logarithmic scale. With each unit on a log-scale, the actual numbers increase tenfold; the log of 10 is 1 because 10 = 10 (x 1) (or 10^1, ten to the power of one); the log of 100 is 2 because 100 = 10 x 10 (or 10^2); the log of 1000 is 3 because 1000 = 10 x 10 x 10 (or 10^3), and so on.

They should discuss in pairs or small groups what the graph they plotted actually means, i.e., they should qualitatively interpret the findings. Then have them hand-draw a line into the scatterplot that follows the general tendency that the data points seem to indicate. You might want to sketch an example on the blackboard. Refer back to your previous comments on **linear relationships**, and reiterate them including terms like **slope** and **y-axis intercept**. (What does the slope tell us? What does a steep slope mean, what a more gradual slope? For an x-value of 0 [the y-axis intercept], is the y-value positive or negative, and what does that mean?) If you plan to have students do the optional exercises on regression spelled out below, you may want to teach them at this point how to calculate the regression equation.

Activity 3.3 What Depends on What in Land Use Change?

Goal

Students understand the principles of regression analysis and how regression differs from correlation. They practice simple regression analysis with several short examples.

Skills

- ✔ calculating a regression equation either by hand or in a spreadsheet

- ✔ analytical thinking
- ✔ application of general understanding of regression to the driving forces and LULC change

Material Requirements

Student Worksheet 3.3 (provided)
Suggested or alternative reading on simple regression analysis

Time Requirements

Depending on students' familiarity with calculus and the statistics package they will use, 1 hr for in-class explanation and the calculations. Plus interpretation and writing time.

Task

This is an optional exercise that may be appropriate if your students have the necessary calculus background or if it is one of the goals of the course to teach regression analysis.

Introduce the concept of regression (in contrast to or extension of correlation) and how one would go about calculating a regression coefficient and regression line (model). In regression one of the variables is independent of the other, whereas the other variable depends in magnitude on the first; in correlation analysis, such a statement cannot be made. Correlation only determines whether or not two variables change concurrently, and in which direction that concurrent change points.

Use the data provided in Activity 3.3 (*Student Worksheet 3.3)* to practice this in class (using either calculators or for simplicity, a spreadsheet software, like QPro, Lotus 1-2-3, Excel, or similar easily accessible programs). Students should be reminded of one of the central questions in the study of LULC change, *viz.*, whether and how human driving forces (in this case population) are related to LULC change (what is dependent on what? Why? Why is the regression coefficient not 1?). Activity and explanation might take as much as one class session.

Activity 3.4 Land Use Change and Driving Forces at Different Scales

Goal

Students expand their regression analysis skills, this time finding their own driving forces and LULC data. They will demonstrate care in examining the relationships between driving forces and LULC change, paying special attention to geographic scale.

Skills

- ✔ regression analysis of a human driving force against a type of LULC change
- ✔ analytical thinking

✔ essay writing or other creative presentation of findings (incl. graphics, equations, text)
✔ application of previously acquired knowledge and caution in interpreting findings

Material Requirements

Student Worksheet 3.4 (provided)
Access to previously found or new data used in the regression analysis

Time Requirements

3 days out-of-class work for students (some consultation time with students during office hours should be considered)

Tasks

This activity is also optional, and may be considered a take-home follow-up to the previous activity and capstone piece. Students basically apply all they have learned so far in this and previous activities and undertake a regression on a data set of their own choosing. They may refer back to the problem formulation and data acquisition to state a research question (hypothesis) and to use data already found.

Ask them to present their analysis and findings in either an essay or another creative way, e.g., on a poster or in report form. The emphasis should be on one relationship at different scales. For example, what is the relationship between economic growth and deforestation globally, in the U.S., and in a developing country? Or, what is the relationship between some measure of technological change and the area under permanent crops locally or regionally, nationally and globally? What are the relationships at each scale and what are the differences between them? What might explain the differences (are they due to scale [i.e., aggregation level] or to region-inherent processes)? Also remind students to be careful in their analysis, checking for data quality as much as possible, and to let common sense and caution guide the interpretation.

Note:
Activities 3.3 and 3.4 are more difficult than the previous exercises, and possibly not necessary for students to understand the basic idea of a relationship between two variables, variance or scatter around a line, etc. These exercises are included for students who are familiar with basic statistics, and/or for instructors inclined to briefly introduce regression and its calculation in their course. If students understand the notions of scatter and variance, they will have no difficulty understanding the *Background Information* of Unit 3, in which the relationships between human driving forces and LULC change variables are assessed quantitatively.

Activity 3.5 Film: *Banking on Disaster*

Goal

The film presents one type of land use change in the tropics and is meant to complement the more abstract activities in this unit. Students recognize the concepts of macro forces and LULC change in the very real and humanized realities of the Brazilian Amazon.

Skills

- ✓ film comprehension
- ✓ interpretation of information
- ✓ critical discussion of movie

Material Requirements

A copy of the film "Banking on Disaster" (78 minutes)

> This three-part documentary (produced in 1988 by Bullfrog Films, Inc., Oley, PA as a U-Matic; color) was filmed over a ten-year period exposing the detrimental effects of deforestation, road-building, and colonization in Rondônia, Brazil. The story is told through colonist Renato Ferreira, ecologist Jose Lutzenberger, and the late Seringueiro Union leader Chico Mendes.†

Time Requirements

1 lab session (about 90 minutes for film and short in-class "reaction" time)

Task

Watch the film *Banking on Disaster* -- maybe as a treat at the end of this section. Ask students to take notes on what they think is remarkable, memorable, interesting, or disturbing about it. You may also ask them to pay particular attention to any mention of what they now know are human driving forces (e.g., technological change, population growth, economic development, etc.). Use these comments as a basis for a short in-class reflection on and preliminary discussion of the movie. If you deem it necessary or interesting, give students some background on the situation in Brazil.

Note that the film is longer than most class sessions. Try to show it in an extra or a lab session.

Conceptual Understanding → Problem Formulation → Data Acquisition and Assessment → Data Analysis → Interpretation of Results

Goal

In this last set of activities, students integrate the individual parts of this module by trying to assess what LULC changes mean for them locally, for their region, and for the world. Students should have a final opportunity to "personalize" global change.

Learning Outcomes

After completing this set of activities associated with Unit 3, students should

- have a solid understanding of the critical importance of LULC in the context of global environmental change
- be able to see general connections between human behavior and global change
- see some of the difficult ethical questions involved in dealing with global change.

Choice of Activities

It is neither necessary nor feasible in most cases to complete all activities in a unit. Instead, select at least two or more from each unit, covering a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This portion of the unit contains the following activities:

3.6 Local Change -- Global Forces	-- Investigation of local impacts of global change
3.7 The Personal Land Use Log	-- Tracking personal linkages to global land use
3.8 How Personal is Global Change?	-- Class debate
3.9 What Can We Do About It Anyway?	-- Role play

Suggested Readings

The following readings make connections between land use/land cover change and global change more generally. They also include "lighter" readings that treat individual places over time and embedded in larger processes.

- Riebsame, W.E., W.B. Meyer, and B.L. Turner II. 1994. Modeling land use and cover as part of global environmental change. *Climatic Change* 28: 45-64.
  A scientific text, recommended if students have some basic understanding of the need for modeling of global processes. A good text at the end of this module because it puts LULC explicitly back into the global change context.
- Turner II, Billie L. and K.W. Butzer. 1992. The Columbian encounter and land use change. *Environment* 34, 8: 16-20, 37-44.
  For many North and South Americans, the anniversary of Christopher Columbus's

landfall in the Bahamas over 500 years ago is no cause for celebration. The "Columbian encounter" and the subsequent invasion by Europeans triggered among other things the most destructive era of land-use changes in the Americas. New evidence suggests, however, that native Americans had already significantly altered the landscape, and their influence may have contributed to changes in land cover in Europe as well. One of the easier reads of this module; a good reminder of the fact that humans are *doing* the changing of the landscape. And it's not just happening in the Amazon! Provocative!

- Wheatley, Nadia and Donna Rawlins. 1994. *My place*. Brooklyn, NY: Kane/Miller Book Publ. (First American paperback edition, c. 1989).
  This is an Australian book written for young people that depicts life in Australia at different times in its development by viewing one place in different years while moving backwards from 1988 to 1788.
- Steward, George R. 1983. *Earth abides*. New York: Ballentine Books.
  A novel (ca. 330 pages) written in 1949. It gives a post-apocalyptic vision of the earth, and might serve as a stimulating way to look at the state of the earth at present.
- Finney, Jack. 1970. *Time and again*. Thorndike, ME: G.K. Mall & Co.
  A well-known book of fiction that tells New York history from 1865 to 1898, by traveling through time. Note also that there is a sequel to this book, published in 1995, called *From time to time: A novel* (New York: Simon and Schuster, 303 pages). That one tells the story of the Titanic steamship, again traveling through time.
- Any reading, scientific or "lighter," that captures a local or regional land use/cover change, and that students can try to relate to the global picture. Examples might include deforestation of old growth forest in the Northwest or Northeast, the loss of wild prairie in the Midwest, agricultural and urban pressures on the Everglades or other local wetlands, the South Dakota Badlands as a vivid example of land degradation, urban sprawl onto productive land, etc.

Activity 3.6 Local Change – Global Forces

Goal

Students bring global change back home by investigating how macro driving forces have affected their community. They investigate how changes in one or more interlinked human driving force(s) that are global in scope, e.g., technology or the economy, affect social relations, communities, and the environment locally.

Skills

✓ analytical thinking
✓ making connections across different scales
✓ integrating skills and information of previous activities
✓ data search

✔ semi-formal interviewing
✔ critical text and data interpretation
✔ oral or graphic/pictorial and textual presentation of findings

Material Requirements

Access to the local grange, a farm bureau, a union, an employment office, archives, etc. Some background material and data on the chosen subject (newspaper, journal articles, etc.)
Battery-operated tape recorder (or simply a note pad and pen)
(Maybe a camera)
Suggested or alternative readings

Time Requirements

1-2 weeks of information gathering and preparation of a report (a capstone project)

Task

Many researchers say that, yes, there might be (or is, or will be) global change -- depending on their level of personal certainty about the issues -- and it does require global-level policy responses, but locally is where people ultimately have to deal with global change, i.e., mitigate potential impacts or suffer negative impacts, or maybe even enjoy beneficial consequences, and then respond to all of these. Locally is also where people have to alter behavior, production processes, consumption or reproductive patterns, etc. Causes, impacts, and responses while global in scope and originating at all scales, are carried out at the local level. This final activity encourages students to look at these local-to-global connections.

Students should gain a clear understanding of how changes in one or more interlinked human driving force(s) that are global in scope, e.g., technology or the economy, affect social relations, communities, and the environment locally. Changes in agriculture, to a significant part driven by technological changes in the production and marketing processes, are a prime example. The shift from family farms to agribusiness has profoundly changed the make-up of the U.S. economy, the food production, the condition of the environment, the rural and urban landscapes, the relations between farmers and their land and labor, the relation between urban and rural populations, the relations between land owners and farm workers, the structures of families, and so on. Similar changes are likely to be found with other extractive activities or industries affecting land use and land cover, e.g., in mining or forestry, the cotton mills or manufacturing.

Students should go to the local grange or farm bureau, a union, a historical society or museum etc. to find historical data on a chosen type of activity. For the agriculture example, they might look for data on the number of farms in their community, the size of the farms, the types of farms (what was produced?), the typical family size, number of non-family member workers, etc. Adapt this list for other subjects. In addition, they might look for old photographs and maps in local libraries and archives, and compare them with more recent maps and pictures. Even folk songs or landscape paintings are a wonderful source!

Encourage them to interview their grandparents or other old folks in their neighborhood or community to get a more personalized notion of "the old times." Questions should relate to the kind of work they did, how they felt about their work and how they felt when things changed; how the community looked 30 years ago, 50 years ago; whether they still know everyone in their neighborhood; where their children are now and what they do for a living; what the landscape looked like (four-lane highways where once were grain fields ...), what is most significant about the changes in the environment for them, etc.

Students should also look up in history textbooks or regional histories what the "bigger picture" was over the studied period (or else rely on their knowledge of major changes during that time). For example, the invention and use of barbed wire in the last few decades of the 19th century had a most significant impact on the process of "taming the Wild West," and that was very clearly reflected in land use and land cover changes. Remind students repeatedly to be conscious of the scale at which they are looking (local, regional, national, supranational); how did events at one scale affect processes at another?

This activity can be adapted as work in small groups or pairs. Students should report back to the class with a creative presentation, including visuals and text. If the project is more ambitious, they could produce an exhibit about historical changes of their community, to be put into city hall or a local gallery, which could include photographs, interview excerpts, maps, a time line with significant data, pieces or drawings of old and new technology, etc.

Activity 3.7 The Personal Land Use Log

Goal

Students track all activities, materials, items, and environmental features that imply some form of land use in order to become aware how much they are personally linked with local-to-global land use/cover change.

Skills

✔ maintaining awareness of one thing for one day
✔ analytical thinking
✔ graphic and textual presentation of results

Material Requirements

Supporting Material 3.7 (provided)
Note pad and pen

Time Requirements

1 day

Tasks

Students become aware of how what they use, eat, drink, do, wear, throw away, etc. on a normal day is related to land use and land cover and how it connects them to the rest of the world.

From the Scottish wool socks and the Indonesian cotton shirt we put on in the morning, to the Midwestern cereal we have for breakfast and the West Indian sugar we stir into our Kenyan coffee, to the local road we travel on to school, to the British Columbian paper we write on, to the Idaho potatoes and California vegetables we have for lunch, to the afternoon swim in the tri-state river, to the backyard garden we grow tomatoes in, to the Nebraskan beefsteak for supper and the ball game played in Boston Gardens we watch on TV -- every resource we use and every way in which we use the land is part of the global land cover and land use. Through economic markets and trade we are connected to the land uses in other parts of the world.

Supporting Material 3.7 lists examples of actions with their possible land use/land cover connections by thematic categories. Students should not feel limited to these examples; they simply are meant to help them become aware of the many times a day we are indirectly or directly benefitting from land use or enjoying a specific type of land cover. They should also make deliberate efforts to find out about the origin of the products, i.e., look at clothing labels, ingredients lists, etc. and do a little research on where these came from.

Students should keep a product/item land use log for one day -- or different groups of the class for different part of the day or different groups of items -- and then hand in a clearly organized paper that lists the types of activities that involved land use or land cover, state such connections, and list the countries from which raw material came or where a product was produced. Students may present their results with maps and other graphics.

Activity 3.8 How Personal is Global Change?

Goal

Students participate in a group discussion or debate in which they assess how global changes would or would not impact them personally. This allows students to apply the abstract knowledge they have gained in this module to a concrete time and place, but also to engage with the subject matter on a personal level.

Skills

✔ application of abstract concepts to a concrete local problem
✔ participation in group or panel discussion (arguing, note-taking, processing, evaluating)
✔ text comprehension

Material Requirements

Background Information, Unit 3 (provided)

Time Requirements

20-30 minutes for the debate, not including reading time

Task

Students should have read Unit 3. Then they should debate how they do or don't feel that global changes and land use changes (would) affect them. You might give them a specific example to start thinking or you might want to use some of the starter questions listed under the *Starter Activity* in Unit 1 to kick off the discussion. If the class is very large, split it up into smaller groups and let them discuss the issues. Allow about 20 minutes for that discussion. Alternatively, set up a panel discussion with representatives of different perspectives. In that case, let small groups representing one point of view each meet beforehand to find common ground and to decide on a good strategy for the discussion. For either format, assign individual students to the roles of panel/discussion leader, reporter (taking notes of main arguments and the course of the debate), and process observer (making sure that each panelist/representative gets an adequate amount of time to speak). The instructor functions as an external observer, facilitating light-handedly if necessary. See also *Notes on Active Pedagogy* on strategies of teaching a controversial issue.

A short summary and debriefing at the end of the session with the entire class is recommended to gather the major findings, points of contention and conversion (refer to what the reporters noted during the discussions).

Activity 3.9 What Can We Do About It Anyway?

Goal

In this activity, students are placed in communities in different socioeconomic, political, cultural, and physical environments where they are charged to try to find a compromise in a difficult situation (land use/development decisions). They must addresses ethics (issues of socio-economic, political, intergenerational, and interspecies justice) and practical reality. This activity allows students to see the opportunities and difficulties in making decisions regarding global change.

Skills

✔ identification with different roles
✔ critical thinking
✔ applying abstract ethical principles and ideas in a concrete, personalized context

Material Requirements

Background Information, Unit 3 (especially the *Conclusion*) (provided)

Supporting Materials 3.9a and *3.9b* (provided)

Background readings on environmental problems, living conditions, economic situation, etc. in different parts of the world that highlight the problems people face in their daily lives (optional; at instructor's discretion)

Time Requirements

1 class session, not including possible preparation time for students before class

Task

This activity requires two pieces of preparation before students embark on the actual role play:

(1) if students haven't read the *Background Information* in Unit 3 yet, they should do so before they come to class. It may also help to ask them to read the two scenarios (*Supporting Materials 3.9a/b*); and

(2) students should brainstorm together in class (either in the entire group or in smaller subgroups that then report back to the class) what it would take for a community (rural village, small town, larger urban center, or a metropolis) to be able to respond to some pretty dramatic changes in their regional climate and environment. It's o.k. at this point for the scenario to be rather fuzzy and open-ended. If students have a hard time getting started you might give them some lead questions to think about; you might also divide the class into groups, each assigned to different parts of the world (they should think in terms of level of affluence and economic stability, political context, technological capabilities, institutional set-up, population size, physical environments, and so forth). It may be easier for some to start thinking about what would help by first thinking of what would make life even hard(er), or what would be obstacles? After about 5-7 minutes of brainstorming (with items to consider either collected on the blackboard, an overhead transparency, or by individual reporters), consolidate a list of favorable conditions, aids, necessary or useful conditions, etc. that would assist in the adjustment to a changed environment.

For the role play, depending on class size, divide the class into groups of 5-7 students. There are two scenario hand-outs (*Supporting Materials 3.9a* and *3.9b*) of which enough copies should be available (half the class or several groups get one, the other half/groups get the other scenario; preferably one copy per student). There is likely to be more than one group working with each scenario, a situation that will become interesting at the end of this exercise when the groups report back to the entire class and see how differently they dealt with the same situation.

The scenarios describe two future situations in different parts of the world, facing different types of problems. Each group is made up of members of a community in these different countries, each member with specific problems, assets at hand, and stakes in finding a solution to these problems. In addition, one group member should be an 'outsider' -- an observer sent from a neutral international organization who takes notes on the process and the outcome (the instructor should tell this student what to look out for; see the questions below to be answered after the role play).

The task for each group is to determine what to do about the situation by deciding

- whether or not to choose a confrontational style, or approach the problem in a spirit of cooperation and mutual respect and openness;
- how much weight to give to each position and how to adjudicate between them (degree of democracy);
- which of the means (from the list prepared beforehand) they would employ or try to put in place to bring about a solution.

In short, the activity is an exercise in trying to find a compromise in a difficult situation that addresses ethics (issues of socio-economic, political, intergenerational, and interspecies justice) and practical reality. Because finding such compromises can be extremely difficult and frustrating, the scenario sets group members up **as if they really care**, and really want to make things work (albeit what that means to people differs greatly!). As students take on their roles and play them out, the instructor should wander from group to group and remind them of this attitude. This may not ensure that all groups will find a compromise, but it should reiterate the idea that global change will ultimately be carried out at the local level and that this is where people have to think of adjustments and work it out.

After about 15-20 minutes stop the role play and ask the neutral outside observers to report in no more than 2-3 minutes to the class what happened in their groups:

- What was the problem (needs to be stated only once per scenario)?,
- What process was used and what did it feel like?,
- What were the stumbling blocks?,
- how did the group end up -- any resolution to the problem?, what means did they draw on to assist in the adjustment?, what remains to be resolved?, and
- how would you assess the ethics applied both in the discussion and in the resolution, and the likely effectiveness of their compromise?

After each group has reported, debrief the class with some summary findings, a recognition of common difficulties the groups had, and call for a show of hands on the likelihood that each compromise would be brought about in the "real" world for the given scenarios.

3 Relationships Between Land Use/Cover and Macro-Forces of Change -- Student Worksheet 3.1

Name:

Activity 3.1 Finding Order in Chaos: Scatterplots

The little table below shows two sets of hypothetical data for a rural, developing country. The first data column gives the number of people per household, and the second gives hectares of land that this household (HH) owns and depends on for agricultural production.

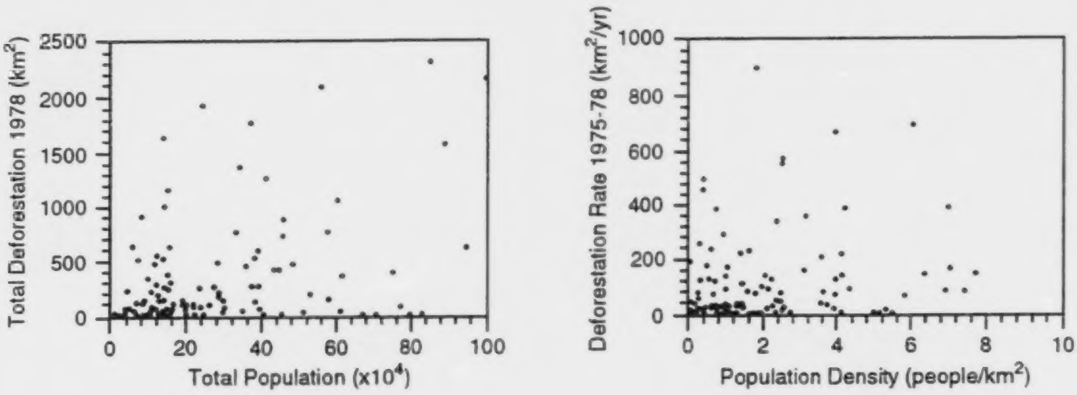
Table 6: Household Size and Land Acreage (A Hypothetical Example)

Household	People/HH	Land (hectares)
1	7	2
2	13	1.5
3	6	2
4	4	1.8
5	8	3.5
6	10	2.5
7	5	1.8
8	9	1
9	2	1.2
10	6	1.9

This is a clear and exact way to present these two data sets, but one that does not allow you to visually recognize at once whether the data indicate any general relationship between number of people per household and the land available to them. For example, one might think that the more people there are, the more land they would have, or maybe, because very poor families are often large, the relationship is inverse, i.e., the more members in the household, the fewer acres per household. Well, we can find out more about the relationship from this data, but it's hard to see it using the table format. (Imagine a big table with hundreds of households sampled!) There is another way to get a quick overview of data: scatterplots.

Look at the graphs on the next page. What you see is called a **scatterplot (also scatter diagram** or **scattergram**). A scatterplot is simply a graph of many individual data points located in a coordinate system. The coordinate system usually is made up of two axes intersecting each other at a right angle. You can think of the axes as some kind of rulers where the scale depends on whatever is being measured along those axes. Each point then is placed in the coordinate system according to its values in the x- (horizontal) and y- (vertical) directions (in our example above, this would mean plotting the values from the first data column along the x-axes, and values from the second data column along the y-axes). Figure 10 gives an example. In the scatterplot on the left each point has a value for population and another one for total area of deforestation in 1978. In the scatterplot on the right, each point has a value for population density and another for the deforestation rate between 1975 and 1978. That could mean that someone took measurements of both of these variables in, say, one area of the Amazon, wrote down these two values, and then went on to a different location and measured the two quantities there, and so on. Together the two values determine **unambiguously** where that point would fall in the coordinate system.

Figure 10: Relationship Between Deforestation and Population: (a) Total Deforestation/ Total Population, (b) Deforestation Rate/Population Density

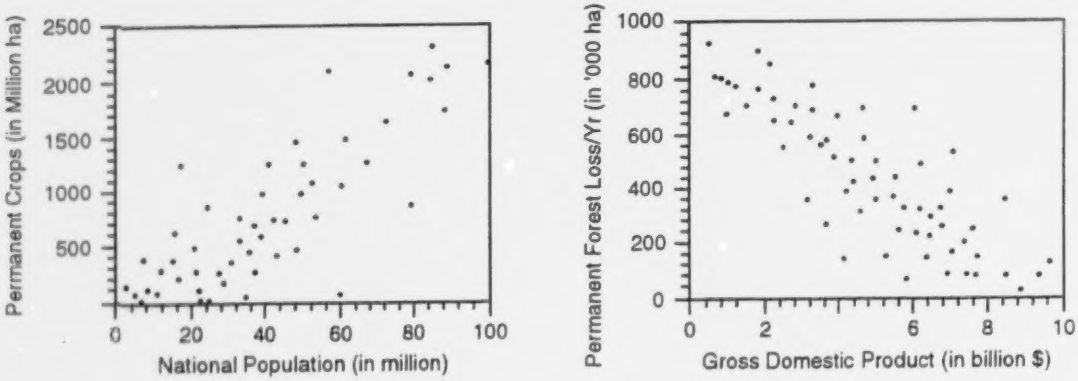


Source: Skole, D. 1995. "Data on land use change: Acquisition, assessment, and analysis." In: *Changes in land use/land cover: A global perspective*, eds. Meyer, W.B. and B.L. Turner, 460. Reproduced with the permission of Cambridge University Press.

Now, why would you want to do that? Usually, you would construct a scatterplot when you have a lot of data and would like to find out whether there is **any kind** of relationship between the two variables that you measured. Note that at this point we don't really care **what kind** of relationship that might be, just **whether** there is one or not. How could you tell?

The scatterplots above might remind you of bugs on a windshield; they just look like a rather chaotic unordered assemblage of points. In the scatterplots in Figure 11, things look a little more orderly: on the left you can see that as values of population get larger, the values of land under permanent crops tend to get larger also. In the scatterplot on the right, values of Gross Domestic Product increase, while those of permanent forest losses tend to simultaneously decrease.

Figure 11: Relationship Between a Macro-Force and a LULC Change (Hypothetical): (a) Permanent Crops/National Population, (b) Permanent Forest Loss/GDP



This sort of relationship is called a **correlation**. Increases in one variable tend to **correlate** with increases/decreases in the other variable. You can tell that this is so from the shape of the "cloud" formed by the data points. So think about what it would mean, if the "cloud" was made up of rather dispersed points vs. if it stretched out as a pretty dense mass to almost form a line? And if two variables were **perfectly** correlated, what would that scatterplot look like? Think about and then discuss this with your neighbor. When you feel you have answers to these questions, note them down below.

Mathematically, the strength of this kind of relationship is expressed by the **correlation coefficient**. The correlation is stronger, the closer the coefficient is to 1 (positively correlated) or -1 (negatively correlated). The correlation is weak, if the correlation coefficient approaches 0. In Figure 9, the graph on the left shows **positive correlation**, the one on the right **negative correlation**.

So what is the general rule as to how values change concurrently if (a) they are not at all correlated, (b) positively correlated, and (c) they are negatively correlated?

A No Correlation -- ______________________________

B Positive Correlation -- ______________________________

C Negative Correlation -- ______________________________

Student Worksheet 3.2 Name:

Activity 3.2 Feeding the Millions

In the blank coordinate system on the next page, label the x and y-axes and plot each data point from the table. Notice that the values in the two columns differ by several orders of magnitude. In order to be better able to plot the data, a linear and a logarithmic axis are used. Read the box on the right if you do not know or recall this distinction.

Each line in the table on the next page contains the two values necessary to locate one point. Use the population density value to find the correct position of a point in the x-direction, and the cropland value to find the position in the y-direction. As you mark each point, write the region or country name above it (as in the given example) so you can tell which is which.

Area	X Population Density (1)	Y Cropland (ha/capita) (2)
World	398	0.28
Africa	212	0.3
N/C America	197	0.65
S. America	166	0.49
Asia	1139	0.15
Europe	1050	0.28
USSR	128	0.81
Oceania	33	1.87
Côte d'Ivoire	380	0.3
Nigeria	1199	0.29
Costa Rica	576	0.18
Mexico	454	0.28
Bolivia	66	0.48
Brazil	174	0.53
China	1201	0.09
India	2811	0.20

Linear means that the actual difference between two points on a scale is the same everywhere on that scale. Between points 1 and 2 is a difference of 1, and so is between points 101 and 102.

Logarithmic, by contrast, means that the actual difference between two points on that scale increases tenfold from one unit to the next. In principle that means that there is an actual difference of 10 between points 0 and 1, but a difference of 100 between points 1 and 2, 1000 between 2 and 3, and so on.

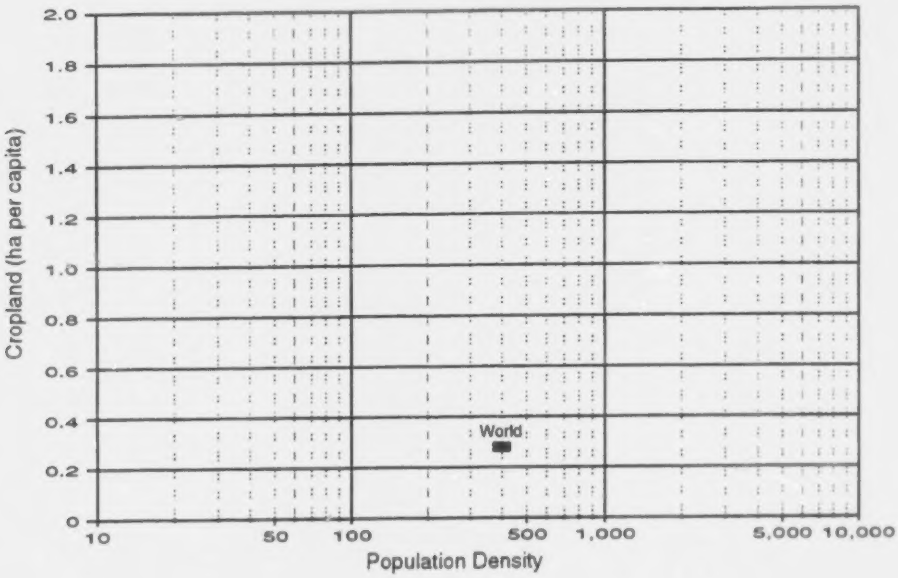
If you have a coordinate system with one axis having a linear and the other a logarithmic scale, the graph is called a **semi-log graph**.

Besides simply plotting the data in the coordinate system, think about what these data tell you. First of all, does population density seem to correlate in any way with the amount of cropland available per person? What would you expect without seeing any data? What reasons might there be for the fact that there is no perfect correlation? How does agricultural production differ from region to region? Where is it more intense? How come? -- Discuss these issues with your neighbor.

Notes:
(1) Population density = people per 1000 ha (in 1989)
(2) In 1989

Source: Extracted from Sage (1994: 280; his Table 2), after World Resources Institute (1990).

Figure 12: Relationship Between Cropland and Population Density, 1989



Source: Extracted from Sage (1994: 280; his Table 2), after World Resources Institute (1990).

When you're finished plotting all the data points, what do you find? Does the "point cloud" indicate any kind of relationship between the two variables? If it does, imagine a straight line drawn right into the cloud that would best represent the shape of the "cloud." For example, if you find that -- generally speaking -- x- and y-values increase concurrently (i.e., they are positively correlated), then draw a straight line with a ruler through the middle of the cloud (beginning somewhere in the lower left and pointing toward the upper right end of the cloud). Note that you don't have to try to intersect all plotted points, although some points might fall right on the line. If the correlation is not perfect, it is simply impossible for all points to fall on a single line. But "eyeball" it such that the line comes closest to as many points as possible.

Try now to draw this line in the graph. Have it intersect the y-axis. The line you just drew is called a **regression line**, and usually one finds it not by "eyeballing" but through calculations. The result of these calculations would be an equation that defines the y-intercept and the slope of the line, the two things you need in order to accurately determine where to draw the line. The general form of that equation looks like this, which is the equation for a straight line:

$y = a^* x + b$ where: a = slope
b = y-intercept

Basically, the regression line falls where the distance between any one point in the scatterplot and this line is minimized. So most points on the line are not what was actually measured, but they are as close as they get to the real data. That's a good basis for predicting unknown values.

Student Worksheet 3.3

Activity 3.3 What Depends on What in Land Use Change?

The table below contains population and land use data. After familiarizing yourself with the concept of regression, enter these data into a spreadsheet, determine which variable (population or land use) is the independent and which one is the dependent variable, and then calculate the regression model (equation) for the four population/land use pairs (population/arable land: population/permanent cropland; population/permanent pasture; population/forest). Plot th[illegible]n a coordinate system using one type of marker for all points belonging to the same populatio[illegible] land use pair. (If you are familiar with the spreadsheet software you are using, you may tell the computer to do this for you.) Then superimpose the regression line (as defined by the y-axes intercept and the slope in your regression model) for each regression pair onto the plotted data. Note the regression equation for each pair below. What can you say about the relationship between population and land use based on this analysis? Write a short summary report (3-5 pp.) with graphs, equations, and your interpretation of the findings. Keep in mind problems of sample size, the relative importance of this driving force, and other issues discussed in this module.

Table 7: World Population and Land Use

Variable	Year					
	1961-1965[1]	**1970**	**1975**	**1980**	**1985**	**1991**
Population[2]	3,288,510	3,694,334	4,076,906	4,449,520	4,916,419	5,295,000[4]
Arable land[3]	1,315,212	1,319,036	1,335,739	1,356,170	1,375,736	1,346,988
Permanent crops	78,555	89,328	94,247	99,323	100,747	94,584
Perm. pasture	3,044,258	3,175,222	3,191,218	3,178,314	3,170,822	3,357,520
Forest	4,169,369	4,190,664	4,169,629	4,111,910	4,086,636	3,861081

[1]: average for the years 1961-65, except for population, for which 1965 data are listed.
[2]: in thousands
[3]: in thousands of hectares
[4]: population for 1990

Sources: Extracted from Young, S. *et al.* 1991. *Appendix: Global land use/cover: Assessment of data and some general relationships.* Report to the Land Use Working Group, Committee for Research on Global Environmental Change, SSRC. Data originally derived from the *FAO Production Yearbooks*. Data in the last column are from FAO. 1992. *FAO Production Yearbook 1991.* New York: United Nations; and FAO. 1992. *UN Demographic Yearbook.* New York: United Nations.

Student Worksheet 3.4

Activity 3.4 Land Use Change and Driving Forces at Different Scales

Investigate the relationship between an indicator variable for one human driving force and one type of land use or land cover of your choice. You may use the research question defined in Activity 2.1 and data sources used and assessed in Activities 2.3-2.6 for this exercise. Enter the data into a spreadsheet, determine which variable is the independent and which one is the dependent variable, then calculate the regression equation and plot the data and the regression line. What is your interpretation of the relationship between the two variables?

If possible, use a global and a regional or local example, and compare and contrast what you find through regression analysis. Is the relationship apparent at both scales? Is it stronger at one scale than at the other? Why could that be? Be cautious in interpreting your findings, remembering the quality of your data. (The Rudel article is a nice example of such a careful analysis and interpretation, but note some of the comments on Rudel's work in the *Background Information* of Unit 3.)

Report your findings with graphs, regression equations, and interpretation in a 3-5 page essay. Alternatively, create a poster that you would display at a conference or another public place where you would want to teach people about these land use change issues at different scales.

3 Relationships Between Land Use/Cover and Macro-Forces of Change -- Answers to Activities

Activity 3.1 Number Crunching and What It All Means

Make sure students understand the concepts of coordinate system, scale on both axes and correlation. Use the two sets of scatterplots to solidify their understanding. The first two scatterplots don't show a clear relationship, of the latter two, the first shows positively correlated, the other negatively correlated values.

Perfect correlation would mean that all points fall on one straight line, whereas **not correlated variables** have randomly dispersed data points in a coordinate system.

Then let students write their rules of thumb for no correlation, positive correlation, and negative correlation.

A **No correlation** -- no trend discernible in the plotted data at all. Data points are randomly distributed.
B **Positive Correlation** -- as values on the x-axis increase, so do values on the y-axis. The trend is one from the origin of the coordinate system up and to the right.
C **Negative Correlation** -- as values on one axis increase, values on the other axis decrease. The trend is, e.g., one from high y-values near the y-axis down and to the right (low x-values).

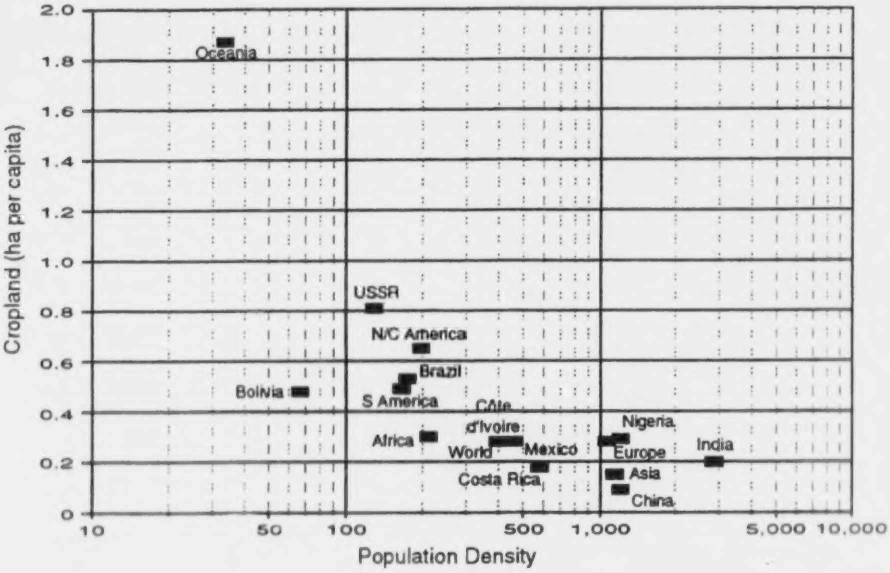
Activity 3.2 Feeding the Millions

Make sure students understand the distinction between a linear and a logarithmic scale. If you do not want to use the mathematical formulations provided in the task description for instructors, draw the two scales one above the other on the blackboard so that the students can visualize the difference. (Say, you have a 1 m yardstick. How many times would it fit on a logarithmic scale between the marker for 0 and 1, between 1 and 2, between 2 and 3, etc.?)

The graph on the next page shows the population density vs. cropland per person data plotted in a semi-log coordinate system with a "tendency" line drawn through it. In their discussion of what the plot actually means, the students should note the following points:

- As population density increases, the ratio of cropland per capita decreases (negative correlation) -- no big surprise. Common sense would have allowed us to come up with this hypothesis.
- But there is no perfect correlation (scatter; points don't all fall on one line). Reasons for that include data-inherent problems, difference in agro-technology, different levels of development of the economy, cultural differences in values and food preferences, physico-natural differences between ecological regions, etc.
- It may be interesting to use some regional examples to illustrate the above points; compare and contrast Nigeria and China, Europe and Asia, Bolivia and Oceania, or North and South America.

Figure 13: Relationship Between Cropland and Population Density, 1989 (Answer)



Source: Extracted from Sage (1994: 280; his Table 2), after World Resources Institute (1990)

Also indicate to students that there is no one line in this hand-held version of a correlation because people see the trends differently, but that a quantitative approach (calculating the slope and y-axis intercept) would result in a definitive line.

Activity 3.3 What Depends on What in Land Use Change?

The task description for instructors already indicates the major difference between correlation and regression. Make sure students understand the difference between these two types of analysis.

The regression analysis for the four population/land use pairs -- with population being the independent and the land use variables the dependent variables -- results in the following values:

Table 8: Results of Regression Analysis (Population/LULC, 1961-1991)

Regression pair	R^2	Slope	Y-intercept
Population/Arable land:	.658	+0.02	1,235,125.8
Population/Permanent crops:	.616	+0.01	56,702
Population/Permanent pasture:	.675	+0.11	2,718,469
Population/Forests:	.695	- 0.14	4,681,090.4

Students should note in their deliberations that these coefficients are fairly large, but in and of themselves they cannot indicate whether population is the strongest driving force (others are not analyzed, so a comparative statement cannot be made). They should also be aware of the fact that only six years entered into the analysis, and that statistical significance is limited by sample size. This fact does not allow major conclusions or inferences about causality.

Students should also demonstrate caution in interpreting the graphs and regression coefficients. Besides assessing the correctness of their calculations, also look for their thoughtfulness and common sense in drawing conclusions from the statistical findings.

Activity 3.4 Land Use Change and Driving Forces at Different Scales

The results of this activity depend entirely on the research question and data used for the analysis. Generally, look for similar indicators as described for the previous activity whether or not students understood the concepts and can thoughtfully apply the analysis to a global change question. In addition, make sure students pay careful attention to scale. Do the results they find at different scales explain the differences? Do these explanations make sense? Do students demonstrate an ability to assess the data they used (to the degree possible) and do these considerations enter into the interpretation?

Activity 3.5 Film: *Banking on Disaster*

Make sure students recognize how abstract driving forces like "technological change" or "economic development" look when grounded in a specific concept. In the discussions students should also recognize the "human face" of land use/cover change.

Activity 3.6 Local Change – Global Forces

The specific results here, again, depend very much on what local example students choose to investigate. Reiterate to students the importance of scale in this exercise. Students should search for and use a variety of data sources and show the necessary scepticism regarding their quality. Note whether they have developed a sensitivity for how global forces might affect communities, people, and the environment locally. You may also want to include students' care and creativity in presenting their findings.

This activity is a great opportunity for the instructor to let go of the reins. Especially if the project is for public display, students will put in much effort and time to show off their best!

Activity 3.7 The Personal Land Use Log

Since practically everything we do and every place we go is somehow related to land use or land cover, students should have no trouble finding many examples to list in their one-day land use log. You might want to set a minimum number of observations to have a basis for comparison of what students hand in. Students should also demonstrate that they have put in some effort to find out about the regional connections between them as users and the places of origin of the items or products they listed. *Supporting Material 3.7* lists examples only roughly. You may want to encourage students to present their land use log in an orderly, structured and/or creative fashion.

Activity 3.8 How Personal is Global Change?

Students explicitly make connections between global processes and their personal lives. This is an informal opportunity to assess students' progress over the module, whether they understood the basic concepts, the linkages between driving forces and land use change, and the connections across scales.

Activity 3.9 What Can We Do About It Anyway?

This final activity is meant to be empowering as well as grounding in reality. Learning about the macro-forces of change should not lead to a fatalistic stance in students *vis-à-vis* the processes shaping their local, social and physical environment. Rather students should understand that what we conceptually call macro-forces are in fact the cumulative results of many individual and community-based decisions over which people do have control, even if they don't feel they do. Decisions about land use must address and balance constraints and opportunities which are political, economic, social, ethical, technological, and environmental in nature. The group reports and the closing debriefing period should bring out this ever-present tension between macro-forces and individual control.

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Supporting Materials

Originals for Overheads

The following pages are meant as originals from which overheads can be made for class review of the material covered in the foregoing units, or else as hand-outs for students as summaries of your lectures if you decide not to give them the entire text to read.

The Human Dimensions of Global Change

- driving/macro forces
- mitigating forces
- proximate sources of change
- impacts
- responses to global change

The *human driving forces* or macro-forces are those fundamental societal forces that in a causal sense link humans to nature and which bring about global environmental changes.

Human Driving Forces of Global Environmental Change

1. Population Change
2. Technological Change
3. Sociocultural/Socioeconomic Organization
    3a. Economic Institutions/Market
    3b. Political Economy/Ecology/Political Institutions
4. Ideology (Beliefs/Attitudes)

(Source: Meyer, Turner, and Young 1990)

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Human mitigating forces are those forces that directly or indirectly impede, alter or counteract human driving forces.

The *proximate sources of change* are those intermediate mechanisms that translate the multi-tiered, complex global driving forces into local human action. Proximate sources of change are the aggregate final activities that result from the interplay of human driving and mitigating forces to directly cause environmental transformations.

Land use is the way in which, and the purposes for which, human beings employ the land and its resources. Examples include farming, mining, and lumbering.

Land cover describes the physical state of the land surface: as in cropland, mountains, or forests.

Land degradation is the decline in productivity and the deterioration of other wanted characteristics (physical, chemical and biological) of the land or soil which is used for a specific purpose.

Central questions in the study of land use/land cover change:
- How are land-use changes contributing to global environmental changes?
- What social-economic factors determine land use, and how will they change?
- How does land use modify processes that influence global change?

A: A Genetic Typology of Global Environmental Change

1. Systemic Change
2. Cumulative Change

(Source: Turner et al. 1990)

Systemic refers to the spatial scale of operation or functioning of a system. Changes of the systemic type occur at any locale and potentially affect the attributes of the physical, (global) system anywhere else or even alter the global state of the system.

Cumulative change refers to the areal or substantive accumulation of localized change. Changes of the cumulative type include those that are local in domain, but which are widely replicated and which in sum constitute change in the whole human environment.

B: An Occurrence-Oriented Typology of Global Environmental Change

1. Changes in material and energy flows
2. Changes in biota
3. Changes in the physical structure of the biosphere

(Source: Turner 1989: 90)

Data Problems

- Need to consider global aggregate and comparative regional conditions and relationships
- Requires accurate global data sets, comparable through time and across space
- Land use/cover data are mostly not standardized and are suspect in terms of accuracy
- Consequently, large margins of potential error

Relationships: Human Driving Forces & Land Use/Cover Δ

- **Global aggregate correlations** between land use changes and driving forces may be on target.
- Their importance for understanding global change must be weighed against untested forces.
- The forces examined here (GDP, population change, energy consumption) more-or-less capture the forces that drive consumption and production.
- Not surprisingly, land use change follows from increases in either, given sufficient time.
- More important to our understanding would be to demonstrate that these forces are correlated, but others are not.
- Such a finding would signify that the production-consumption forces are more fundamental to land use change than the social organizations in which they operate (not possible yet).
- **Regional comparative correlations** may also be on target, and not contradictory to global aggregate patterns.
- The latter are averages, created by a range of relationships differing across space.
- This indicates that a proposed macro-force changes its relationship with land use changes as the conditions in question vary.
- Contextual conditions need to be thoroughly assessed and worked out for individual regions in order to know what they are and how they influence macro-forces or interactions among them.

Conclusions

- In and of themselves, the data -- or the lack and questionable quality thereof -- are a major impediment to our better understanding of the causes of global environmental change.
- Similarly fundamental is the lack of a theoretical foundation that adequately captures the dynamics between land use change and human driving forces at *different* and *between* scales.
- The analyses showed that whether or not we find a relationship between two variables also depends on scale and the specific regional contexts of land use and driving force in question.
- There is *no single answer* to "what driving forces cause what land use/cover change and how much of it?"
- The fundamental issues in answering the question how driving forces are related to land use changes severely limits our ability to even begin to answer other questions regarding the kinds of impacts to be expected from global change and the possible responses to them.
- There is a need for "good" answers to these questions: solid and soon! (Or is it: solid *or* soon?)
- Dilemmas result for scientists, policy makers and lay people.
- Meanwhile there is a hot debate between the "alarmist, red-flag wavers" and the "wait-and-see, thumbs-up optimists" while others turn a blind eye on these enormously complex, often hidden, and politically heavily charged problems.
- We have high stakes to lose with global change: face, political clout, investments, human health, environmental assets, and people.
- Global change -- while requiring global responses -- ultimately is a personal matter: it is about the ethical decisions each one of us does or doesn't make, the behaviors of consumption and reproduction each one of us does or doesn't reconsider and maybe change, and the bonus and onus each one of us gets to carry away from a changed ecological and human environment.

Supporting Materials for the Activities

The following pages contain all those Supporting Materials referred to in the Activities. They are numbered according to the activity in which they are used. For example, *Supporting Material 1.1* would accompany Activity 1.1. Use these materials as overheads or hand-outs for students, especially when other resources are not available at your institution.

Taking notes that make sense -- even in a year from now ...

As you work through the reading assignments for this and the following exercises, do not just read the articles, or just underline important passages. For understanding and remembering the arguments it is even more important to take notes on what you read. Taking concise, comprehensive, but not too long notes is a big step in preparing for classes and exams. The primary purpose of taking notes is to produce a brief overview of a text to help your memory recall the larger story of which they speak. If you are experienced in taking good notes, proceed to do so as you read your assigned materials. If you feel you could use some guidance in how to improve on this skill, follow the steps below.

Articles that are written well have at least:

* a descriptive and/or provocative **title**,

* a compelling or at least an internally consistent **argument**,

* an apparent, intuitively logical, and hierarchical **structure** (look for subtitles!),

* an obvious **paragraph separation and sequence**, and

* a clear, understandable **language** (including correct grammar and spelling, reasonably short sentences, explanation for new or foreign terms, avoidance of unnecessary jargon and verbiage, etc.).

1 Gather the most obvious clues!

Browse through your article and note on a piece of paper its structure by writing down the title and all the subtitles of individual sections in the sequence in which they appear in the text. Indent all the subtitles that belong to the same logical section (to the same level in the hierarchy of importance) by the same amount so you know they are of similar importance and belong logically together. If there are no subtitles you need to look at the text a bit more closely: is there a sequence of themes that the author(s) go through in the course of the text? If you can discern them, list them in the sequence in which they appear! (You may also group them later into logical classes if you can discern any.)

Example:

Neglected dimensions of global land-use change: Reflections and data
- The diversity of human land use
- Human driving forces: a conceptual framework
- Data on land-use change
  - Global trends
  - Regional trends
  - Country trends in land use
- Intensification of land use
- Population growth and land-use change
- The effect of transportation and communication infrastructure
- Lifestyles and land-use change
- The myth of past harmony between population and land
- Conclusion
- (Notes)

2 **Put your mind's antennas out!**

You can signal your brain to activate all the pertinent knowledge you already have about a subject by looking for titles and subtitles, as well as the logical structure of the text. These are the first hints as to the author's main argument in the text. The more conscious you become of these clues, the easier it will be for you to actually take in what someone writes.

So looking back at the above example, **what do you expect the text to be about**? (Note that in this exercise we are just being explicit about what your brain does automatically, whenever you get new information!).

3 **Read the text (again)!**

If you have not read the article yet, do so now. Stop once in a while and recall what you thought the text would be about. Are your expectations met? (If they are not, you will probably be quite frustrated and most likely bored!)

4 **Note the main argument!**

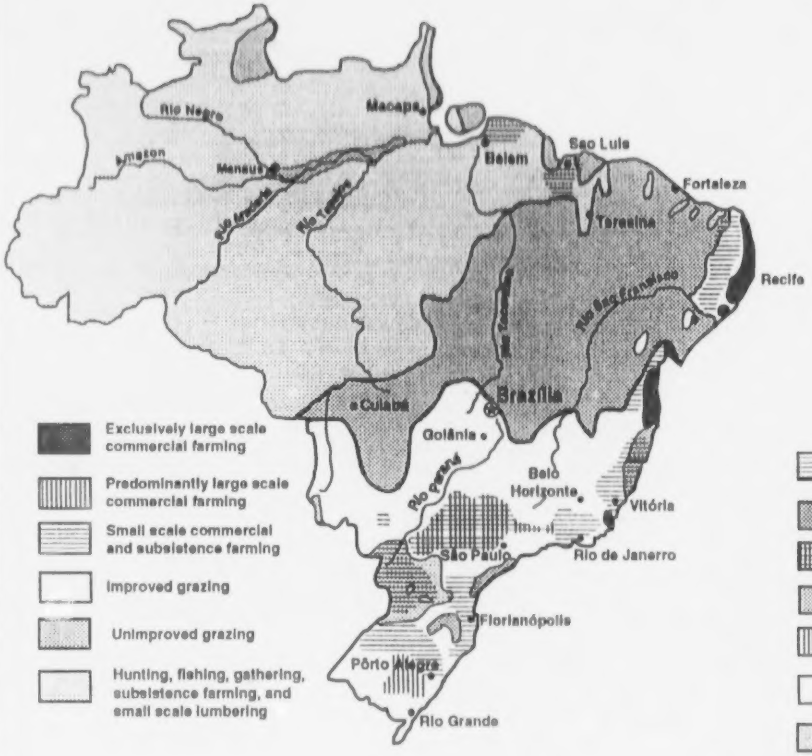
Given your expectation of the text and reading through it, what would you say is its main argument? In other words, if you were to explain the gist of the article to a friend who hadn't read it, what would you say?

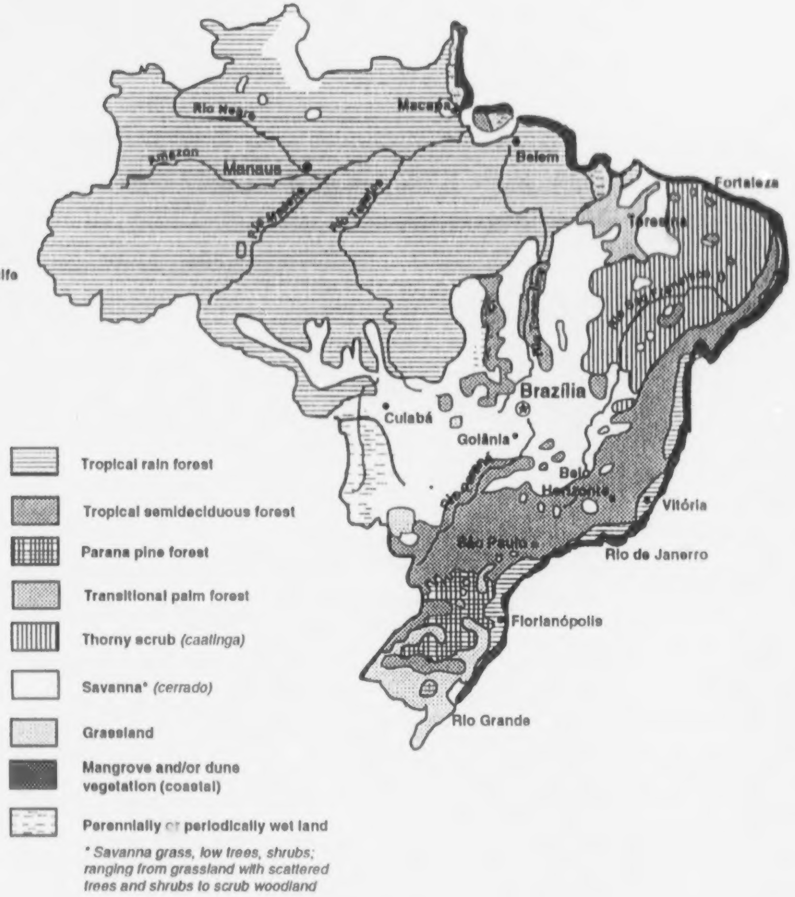
5 **Concisely list the supporting arguments under each heading (or subtitle)!**

Every argument needs supporting arguments, data, and other evidence to be convincing. As you go through the text once more -- paragraph by paragraph -- list in keyword style or short sentences what the supporting evidence and arguments the author(s) presented. If you can't decide what is important and what is not (and thus should be omitted from this listing), ask yourself whether you found it important to know this particular item to understand the logic behind the argument. If not, leave it out! Everything that is not essential to the argument you are most likely to forget anyway.

6 **Check whether it makes sense!**

Once you're through with Steps 1-5, look over your notes once again and see whether they make sense. (The best test is really three days after taking the notes, i.e. when you're already somewhat removed from having read the article. If they still makes good sense, you took good notes!) If you feel like somewhere you lost the thread of the argument, fill in the blanks. Also compare the length of your notes with the length of the article: if your notes are as long as the original article, you simply paraphrased the text. Notes by definition are short and never as prosaic as an essay!





Source: CIA. 1977. Brazil. Washington, DC: Central Intelligence Agency.

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The problem: I am really interested in whether population growth (the macro force) forces societies to change the way it produces agricultural products (proximate source of change), and, if so, what that means in terms of changes in the landscape (land cover).

One researchable question: Does the change in US population between 1850 and 1990 correlate with concurrent changes in intensity of agricultural production and soil degradation?

Underlying assumptions:

☐ Population growth has in fact causal powers ("...forces..."); note that in picking correlation as the method of choice, the causality assumption has been weakened to simple temporal coincidence.

☐ The kind of farming affects how a landscape looks ("..and what that means in terms of...")

☐ The change in US farming during this time was doubtlessly one of intensification ("...changes in intensity...")

☐ This change has negative imlications for effective land use ("...soil degradation")

Operationalization:

Variable	Measure	Why this one?
Change in US population	Absolute difference between US population in census yrs between 1850 and 1990	Obvious choice; absolute figures easier to relate to than percentages
Change in intensity of agricultural production	Total amount of wheat yields from US farms per total area of land for wheat production (in tons/ha, for 1850-1990)	Intensity needs a relative measure; wheat is a very important grain in the US;
Soil degradation	Amount of nutrients (C, N, Ca, Mg) in typical (representative) soil for wheat production minus the input of these nutrients through fertilizers	This difference reflects soil fertility (an indicator showing potential soil degradation). Note that it is virtually impossible to find such data for the time prior to the 1930s; alternative measures are equally hard to find.

The Personal Land Use Log

This is a list of examples of familiar products and activities which have an impact on land use/land cover. In fact, almost everything we do somehow relates to one or the other. Use, but don't feel limited to, these suggestions while recording your personal land use log.

Food and Drinks	**Land Use/Land Cover**	**Some Affected Regions**
bread and cereal	grain fields	US Midwest
fruit and vegetables	vegetable fields, gardens, greenhouses, orchards	California, The Netherlands, Massachusetts, tropical areas
meat	fodder (e.g. corn) fields, pastures	Corn belt, Pampas
butter, cheese and other milk products	pastures, meadows, stables	Wisconsin, Vermont
juices, wine, beer	orchards, vineyards, hops fields	California, France, Germany
coffee, tea, hot chocolate	coffee, tea or cocoa plantations	East & West Africa, China
CLOTHING		
wool jackets, socks	meadows	Ireland, Iceland, Scotland
jeans, t-shirts (cotton)	cotton fields/plantations	Southeastern US, Asia
leather shoes	meadows, water bodies, etc.	New England, Middle East
USE/LUXURY ITEMS		
cars (metal, rubber, glass)	iron ore mines, quartz quarries, rubber plantations	Quebec, South Africa Brazil
plastic articles (bags, containers, toys, utensils)	petroleum fields	Texas, Iran
furniture (wood, plastic, steel)	forests, iron ore mines, petroleum fields	Scandinavia, Central Europe, Saudi Arabia
WORK-RELATED ACTIVITIES		
writing/printing on paper or reading books	coniferous forests, water bodies	Western Canadian provinces, Southeast Asia
constructions	(Sub)urban areas, forests, rock and sand pits	anywhere
truck driving	highways, container parks, petroleum fields	across the US Middle East
LEISURE TIME ACTIVITIES		
playing ball	ball parks, lawns, stadiums	anywhere
running or biking	pavement, roads	anywhere
taking photographs	silver ore mines, forests, the landscapes that we capture	British Columbia, South Africa anywhere
OTHER		
electricity	coal and uranium mines, rivers, wind mill fields	Pennsylvania, Germany, South Africa, James Bay, Arizona

A Beach Town Somewhere on the Eastern Seaboard...

It is the year 2050, and this is Beachtown, a town of about 2000 permanent residents somewhere on the southern Atlantic coast of the US. Those of us who aren't quite retired yet have jobs either in the service sector here, or we work in the large inland cities. Our beaches are sandy and beautiful, although not much is left of them since climate change has caused the sea level to rise about 1 ft since the beginning of this century; as a consequence, beach erosion has steadily eaten away at our most important resource. We really depend on our beach: tourism is our most important industry, and the beach is what people come here for (by the thousands each summer!) ... Well, some of them also like to play golf, so that has put a lot of development pressure on the agricultural land and the wetlands -- developers buy out farmers and want to fill in the wetlands so they can build more golf courses, gated communities (private developments closed to the general public), hotel complexes, and entertainment facilities. And some of us would really like to see more of that happen: more golf courses, hotels, and entertainment parks mean more tourists, more jobs, more revenues, higher land prices, and thus more tax income to the community. But it looks like it will also mean getting into trouble with the environmentalists and the people who fish, even if they're just doing it part time or for sport: they care about the wetlands as nurseries for marine species, and a whole bunch of other species, especially birds. Some of these birds are here year-round, but many of them come through twice a year to breed or to stop over on their North-South migration. We've noted a marked decline in recent decades because so much of the wetlands have already been lost. And then, of course, we have to think about protecting our beachfront property against coastal hazards: hurricanes, winter storms, and the flooding that often goes along with them. A long time ago, the federal government stopped providing insurance through the National Flood Insurance Program, so all we can hope for is some money from the state, but with the state it's "iffy;" nobody there seems to give any clear direction as to which way to go; they want to strengthen the tourist sector, cut down on public expenditure (like infrastructure that would have to be built if we developed the coast more, or for hazard mitigation), and claim that the state has a good environmental record -- all at the same time. All we know is: we have to do something....

The city council has called a public hearing to decide on the future direction of Beachtown. The following people attend this meeting:

- the mayor of Beachtown
- a developer
- an environmentalist
- a beachfront property owner
- an employee of the Chamber of Commerce
- a hotel owner
- a retiree
- a part-time fisher/ part-time bar tender

Task:

Each student in your group should choose one role (others are possible by group agreement), and participate in the hearing/discussions. *Each one of you really cares* about Beachtown, but of course you all have different interests, ethics, and stakes in its future. Your charge is to decide together over the most appropriate land use of Beachtown, considering the many facets of this problem.

A Beach Village Somewhere on the Indian Ocean...

It is the year 2050, and this is Beachvillage, a community of about 600 people somewhere on the Mozambique shores of the Indian Ocean. Most of us here earn our living either in fishing or in the sisal plantations or date palm groves owned by rich farmers -- some of them are absentee landowners. Some of the men from the village also travel further inland for part of the year to work on cotton and citrus fruit plantations while the women stay here, and carry almost the entire burden of raising the kids and working the fields around the village for their daily food. Overall, we can make a living, but just barely. Prices for fish and crops are low, and we can't compete with the big farmers. The climate seems to have become less predictable, too ... we never know whether we will have enough rain! Most of the families in Beachvillage have at least four children, and if one of them (in all likelihood the oldest son) is sent to school, he's lucky! In the past couple of decades we had many of these educated, and some of the non-educated, youngsters leave the village for Nampula and other big cities -- hardly any of them ever come back! Because of our beautiful beaches we recently had some European developers come to speak to our village council about buying land from us so they can build a big hotel. Ever since the political situation has calmed down in our country, people from Europe feel safe enough to come to Mozambique for vacation. The developers promised we could keep on living like we do now on the remaining land; and even better, we could get jobs in their hotel. They said they could see how more of our young people would stay in the village that way. Well, we don't know... Shortly after the developers left, we had people from the World Wildlife Fund come to our village and tell us we should not sell our land to the hotel people; they told us it would lead to pollution of our coastal waters, diminishing our fish resources, spoil our beaches, kill the turtles that lay their eggs in the beach sand every year, and that the developers would probably cut down the mangroves just south of our village, too. We occasionally cut some mangrove trees too for fuel, but we would never destroy the whole forest; that's where the fish and shrimp spawn, and the mangroves slow down the storms coming in from the ocean -- we need them for protection. It's as if all of a sudden our piece of the coast was the most wanted piece along the world's shores; after the WWF people left, a regional development group associated with researchers from Mozambique University came here with a plan to improve our agricultural income. For that to work out, other villages from around the area all have to collaborate, so that we can create a viable and reliable market for our products, and get good prices for our crops. It's not clear yet, what other villages are going to do. But then again, we're not sure yet either. All we know is: we have to do something....

The oldest members of our village have asked the Beachvillage Council to come together and discuss the problem. The following people attend the meeting:

- the head of Beachvillage Council
- one of the oldest people in the village
- a young man who wants to work in the hotel
- a mother of five children
- a woman with family in one of the neighboring villages
- a plantation farmer
- a fisherman who also farms
- an older man with formal education in environmental studies
- a young farmer who is friends with the regional developm't cooperative

Task: Each student in your group should choose one role (others are possible by group agreement), and participate in the village council discussions. *Each one of you really cares* about Beachvillage, but of course you all have different interests, ethics, and stakes in its future. Your charge is to decide together about the most appropriate land use for Beachvillage, considering the many facets of this problem.

Additional References

The following papers are meant as either

- background reading for the instructor,
- alternatives to the suggested readings, or
- basic material for specific courses built around the given themes.

Generally speaking, articles from *Environment*, *BioScience*, *Ambio*, and *Research & Exploration* are relatively easy texts, whereas papers from the *Annals of the Association of American Geographers*, *Professional Geographer*, *Progress in Human Geography, Climate Change*, *Global Environmental Change*, *Ecology*, *Annual Review of Ecology and Systematics, Science*, *PE&RS*, *Journal of Forestry*, and scientific monographs or anthologies are more "heavy duty" and may require the instructor's guidance. Alternatively, material contained in those papers could be related to students through the instructor in short, informal lectures.

Global Change – Geographical Approaches

Clark, William C. 1988. The Human dimensions of global environmental change. In: *Towards an understanding of global change: Initial priorities for U.S. contributions to the International Geosphere-Biosphere Program*, 134-200. National Academy Press, Washington, DC.

Kotlyakov, Vladimir M. *et al.* 1988. Global change: Geographic approaches: A review. Proceedings, National Academy of Sciences (US), 85: 5986-5991.

Mackenzie, Fred T. 1995. *Our changing planet: An introduction to earth system science and global environmental change*. Prentice Hall: Englewood Cliffs, NJ.
A resource book worth putting on reserve for the class as background to the module and course, especially Introduction to Physical Geography or Environmental Science courses.

Riebsame, William E. 1990. Anthropogenic climate change and a new paradigm in natural resource planning. *Professional Geographer* 42, 1: 1-12.

Roberts, Neil, ed. 1994. *The changing global environment*. Blackwell, Oxford.
An alternative to Mackenzie, worth putting on reserve for the class as background to the module and course, especially Introduction to Physical Geography or Environmental Science courses.

Land Use/Land Cover Change – General Readings

Clark, James S. and Chantal D. Reid. 1993. What are nonlinear responses at the biome level?

In: *Assessing surprises and nonlinearities in greenhouse warming*. Proceedings of an Interdisciplinary Workshop, eds. Joel Darmstadter & Michael A. Toman, 53-89, Resources for the Future: Washington, DC.
A chapter for more advanced students with some background in Biogeography or similar areas.

Clark, William C. 1987. Scale relationships in the interaction of climate, ecosystems, and societies. In: *Forecasting in the social and natural sciences*, eds. K.C. Land and S.H. Schneider, 337-378. D. Reidel, Dordrecht, NL.

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Houghton, R.A. 1994. The world-wide extent of land-use change. *BioScience* 44, 5: 305-313.

Meyer, William B. 1995. Past and present land use and land cover in the USA. *Consequences* 1, 1: 24-33.

Meyer, William B. and Billie L. Turner II. 1996. Land-use/land-cover change: Challenges for geographers. *GeoJournal* 39, 3: 237-240.

Meyer, William B. and Billie L. Turner II., eds. 1994. *Changes in land use and land cover: A global perspective*. Cambridge: Cambridge University Press.

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Ojima, D.S., K.A. Galvin, and B.L. Turner II. 1994. The global impact of land use change. *BioScience* 44, 5: 300-304.

Richards, John F. 1990. Land transformation. In: *The earth as transformed by human action*, eds. B.L. Turner II *et al.*, 163-178, Cambridge University Press: Cambridge, UK.

Riebsame, W.E. *et al.* 1994. Integrated modeling of land use and cover change. *BioScience* 44, 5: 350-356.

Riebsame, W.E., W.B. Meyer, and B.L. Turner II. 1994. Modeling land use and cover as part of global environmental change. *Climatic Change* 28: 45-64.

Turner II, Billie L. and K.W. Butzer. 1992. The Columbian encounter and land use change. *Environment* 34, 8: 16-20, 37-44.

Turner II, Billie L., W.B. Meyer, and D. Skole. 1994. Global land-use/land-cover change: Towards an integrated study. *Ambio* 23: 91-95.

Turner II, Billie L., R. Moss, and D. Skole, eds. 1993. *Relating land use and global land-cover change*. IGBP Report No. 24/HDP Report No.5. Stockholm, Sweden.

Urban, F. and T. Volltran. 1984. Patterns and trends in world agricultural land use. *Foreign Agricultural Economics Report # 198.* U.S. Dept. of Agriculture.

Whitby, M. and J. Ollernshaw, eds. 1988. *Land use and the European environment.* London & New York: Belhaven Press.

Human Driving Forces

Grübler, A. 1994. Technology. In: *Changes in land use and land cover: A global perspective,* eds. William B. Meyer and Billie L. Turner II, 287-328. Cambridge University Press: New York.

Rockwell, Richard C. 1994. Culture and cultural change. In: *Changes in land use and land cover: A global perspective, eds.* William B. Meyer and Billie L. Turner II, 357-382. Cambridge University Press: New York.

Sage, Colin. 1994. Population and income. In: *Changes in land use and land cover: A global perspective,* eds. William B. Meyer and Billie L. Turner II, 263-286. Cambridge University Press: New York.

Sanderson, Steven. 1994. Political economic institutions. In: *Changes in land use and land cover: A global perspective,* eds. William B. Meyer and Billie L. Turner II, 329-356. Cambridge University Press: New York.

Simon, J.L. 1980. Resource, population, environment: An oversupply of false bad news. *Science* 208: 1431-1437.

Turner II, B.L. 1991. Thoughts on linking the physical and the human sciences in the study of global environmental change. *Research and Exploration* 7: 133-135.

Turner II, B.L. *et al.* 1990. Two types of global environmental change: Definitional and spatial scale issues in their human dimensions. *Global Environmental Change* 1: 14-22.

Forests

Alig, R.J. *et al.* 1983. Long-range projections of forest area changes. *Journal of Forestry* 81: 723-727.

Allen, J.C. and D.F. Barnes. 1985. The causes of deforestation in developing countries. *Annals of the Association of American Geographers* 75: 163-184.

Barnett, Adrian. 1992. *Deserts of trees: The environmental and social impacts of large-scale tropical reforestation in response to global climate change.* London: Friends of the Earth.

Barraclough, Solon L. and Krishna B. Ghimire. 1996. Deforestation in Tanzania: beyond simplistic generalizations. *The Ecologist* 26, 3: 104-109.

Browder, J.O. 1988. The social cost of rain forest destruction: A critique of the "hamburger" Debate. *Interciencia* 13: 115-120.

Goldammer, J.G., ed. 1992. *Tropical forests in transition: Ecology of natural and anthropogenic disturbance processes.* Basel, Boston: Birkhauser Verlag.

International Institute for Applied Systems Analysis (IIASA). 1994. *Options.* Winter issue dedicated to Siberian Forests and IIASA's Siberian Forests Data Base and study.

Kummer, David M. and B.L. Turner II. 1994. The human causes of deforestation in Southeast Asia. *BioScience* 44, 5: 323-328.

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Shen, Sinyan (Int. Boreal Forest Research Association). 1993. *Boreal forests and global change: IBFRA papers.* Woodridge, IL: Institute for World Resource Research. Or: *World Resource Review* 5, 1.

Skole, D.L. *et al.* 1994. Physical and human dimensions of deforestation in Amazonia. *BioScience* 44, 5: 314-322.

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Tuomisto, H. *et al.* 1995. Dissecting Amazonian biodiversity. *Science* 269, 7 July: 63-66.

U.S. Dept. Of Agriculture. 1994. *Global change and forests*. Agriculture Information Bulletin, no. 687. U.S. Dept. Of Agriculture: Washington, DC.

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US Forest Service. 1980. *An assessment of the forest and rangeland situation in the United States.* Washington, D.C.: US Department of Agriculture.

Grassland/Pasture

Dodd, Jerrold L. 1994. Desertification and degradation in Sub-Saharan Africa. *BioScience* 44, 1: 28-34.

Graetz, Dean. 1994. Grasslands. In: *Changes in land use and land cover: A global perspective,* eds. William B. Meyer and Billie L. Turner II, 125-148. Cambridge University Press: New York.

Milton, Suzanne J. *et al.* 1994. A conceptual model of arid rangeland degradation. *BioScience* 44, 2: 70-76.

Solbrig, O.T. and M.D. Young. 1992. Towards a sustainable and equitable future for savannas. *Environment* 43: 7-15, 32-35.

Cropland

Billsborrow, R.E. and H.W.O. Okoth-Ogendo. 1992. Population driven changes in land use in developing countries. *Ambio* 21: 27-45.

Dale, V.H. *et al.* 1993. Causes and effects of land use change in Central Rondônia, Brazil. *Photogrammetric Engineering & Remote Sensing* 59, 6: 997-1005.

Helms, Susan, Robert Mendelsohn, and Jim Neumann. 1996. The impact of climate change on agriculture. Editorial essay. *Climate Change* 33, 1: 1-6.

Revelle, R. 1984. The world supply of agricultural land. In: *Resourceful earth*, eds. J.L. Simon and H. Kahn, 184-201. Blackwell: Oxford.

Richards, J.F. 1986. World environmental history and economic development. In: *Sustainable development of the biosphere,* eds. W.C. Clarke and R.E. Munn, 53-71. Cambridge University Press: Cambridge.

Rosenzweig, Cynthia and Daniel Hillel. 1993. Agriculture in a greenhouse world. *Research and Exploration* 9, 2: 208-221.

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Eisma, D., ed. 1995. *Climate change: impact on coastal habitation.* Lewis Publ.: Boca Raton. Contains chapters on the history and dynamics of sea-level change, and the impacts on human-made structures in the coastal areas as well as on temperate and tropical coastal ecosystems.

Firth, Penelope and Stuart B. Fisher. 1992. *Global climate change and freshwater ecosystems.* New York: Springer Verlag.
Based on conference proceedings. Contains at least one article pertinent to northern freshwater wetlands.

Lowe, M.S. and R.D. Thompson. 1992. Use and abuse of wetlands. In: *Environmental issues in the 1990s*, ed. A. Mannion. J. Wiley & Sons: Chichester.

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Warren, R. Scott and William A. Neiring.1993. Vegetation change on a northeast tidal marsh: Interaction of sea-level rise and marsh accretion. *Ecology* 74, 1: 96-103.

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Berry, Brain J. L. 1990. Urbanization. In: *The earth as transformed by human action*, eds. B.L. Turner II *et al.*, 103-120, Cambridge University Press: Cambridge, UK.

Brunn, Stanley D. and Jack F. Williams, eds. 1993. *Cities of the world: World regional urban development.* 2nd ed. New York: Harper Colins.
An introductory college text. Chapter 1 gives a general and conceptual overview of urbanization, then the book is organized by region. It ends with "Cities of the future," a chapter that goes beyond land use changes into the sociological implications of current trends.

Fishman, Robert. 1990. America's new city: Megalopolis unbound. *The Wilson Quarterly*, Winter: 25-45.
An easy read on the problem of urban sprawl of America's city's onto highly productive land and into beautiful recreational areas. Also reprinted in *Annual Editions: Urban Society*. 7th ed., ed. Fred Siegel, 22-30. Guilford, CT: The Dushkin Publishing Group.

Data Sources for this Module and Beyond

Food and Agriculture Organization (FAO). 1946-present. *Production yearbook.* (annual publication). Rome: FAO.

Food and Agriculture Organization (FAO). 1948-present. *World crop and livestock statistics.* Rome: FAO.

Food and Agriculture Organization (FAO). 1983. *State of food and agriculture 1982.* Rome: FAO.

Food and Agriculture Organization (FAO)/Economic Commission for Europe (ECE). 1985. *The forest resources of the ECE region.* Rome: FAO/ECE.

Food and Agriculture Organization (FAO).1984. *Land, food and people*. Rome: FAO.

United Nations. *Statistical yearbook.* Annual publication. New York: United Nations.

United Nations Environmental Program (UNEP). 1987-1989. *Environmental data report.* Oxford.

World Bank, 1984. *China -- agriculture to the year 2000 -- prospects and options.* Washington, D.C.: World Bank.

World Resources Institute and International Institute for Environment and Development. 1986, 87, 88, 90. *World resources 1986, 1987, 1988-89, 1990-91.* New York: Basic Books. (And similar later publications.)

See also the following articles and book chapters as information, assessment, and critical comment on the above data sources:

Skole, David L. 1994. Data on global land-cover change: Acquisition, assessment and analysis. In: *Changes in land use and land cover: A global perspective*, eds. W.B. Meyer and B.L.

Turner II, 437-471, Cambridge: Cambridge University Press.

Kelmelis, John and Fran Rowland. 1994. Appendix 1: Data collections useful for analysis of land use/land cover change. In: *Changes in land use and land cover: A global perspective*, eds. W.B. Meyer and B.L. Turner II, 473-507, Cambridge: Cambridge University Press.

Thomas, Michael R. 1993. CIESIN: Providing access to global environmental change data and information. *Impact Assessment* 11, 3: 307-320.

Other Supporting Aids

Computer-Based Literature Search:

Instructors and/or students may also use computer- and Internet-based library services (e.g., OCLC's *First Search*, the Library of Congress, the Social Science Index, and similar services) to either retrieve texts not available at local libraries, or to order them via interlibrary loan.

Internet Data Sources:

The following list of sites on the Internet comprises a very small selection of electronic information sources. Students versed in navigating the Internet will have no trouble retrieving the information and data available through this avenue. When students are not yet familiar with this medium, instructors may use the opportunity of a module that introduces students to very basic research skills, to also help them use the Internet which should be available at almost all institutions. In that case, the instructor should write up a page of step-by-step instructions for the Internet-novice in the computer-lingo used at her/his institution.

CIESIN The Kiosk: http://www.ciesin.org/kiosk/home.html

The Consortium for International Earth Science Information Network (CIESIN)'s Socioeconomic Data and Applications Center (SEDAC) facilitates information sharing and discussion. It makes data, studies (after peer review), reports and working papers related to global environmental change more accessible than they otherwise would be. Browse through the following options:

- SEDAC Policy Application Issues (with info on population, land use, and emissions)
- SEDAC Information Gateway Issues
- General Global Change Material
- Unpublished Papers (cf. the "CIESIN Human Dimensions Kiosk")
- Electronic Bookshelf ... and much more....

Other internet access venues to CIESIN and SEDAC:
http://wwwgateway.ciesin.org/
http://sedac.ciesin.org/

The Climate Action Network Newsletter: http://www.igc.apc.org/climate/Eco.html

At this site you can retrieve the *Eco*-Newsletter of the Climate Action Network (CAN), published at the UN Climate talks. *Eco* contains the views of environmental organizations participating in CAN.

CDIAC: **http://www.ornl.gov/MajorPrograms/cdiac.html**

The Oak Ridge National Laboratory's Carbon Dioxide Information Analysis Center (CDIAC) provides climate related information (carbon dioxide and other greenhouse gases). CDIAC also assures data quality, documents the data, distributes related reports and produces a newsletter (*CDIAC COMMUNICATIONS*). Data are most easily available as Numeric Data packages (NDPs) retrieved via FTP. For complete information on NDPs, contact CDIAC via e-mail at cdp@stc10.ctd.ornl.gov.

EOSDIS: **http://ecsinfo.hitc.com and http://eos.nasa.gov/imswelcome**

The Earth Observing System (EOS) is an integral part of NASA's Mission to Planet Earth. Its Data and Information System (EOSDIS) manages and makes available satellite and other earth science data gathered through this mission.

USGS: **http://www.usgs.gov/**

Mostly US data for land use/land cover at various scales; also information on hazards.

World Resources Institute: **http://www.wri.org/wri/wr-96-97/**

The World Resources Institutes electronic version of the bi-annual World Resources Publication, an assessment of the state of the world. The 1996-97 publication has a large section on urban developments.

U.S. Global Change Research Program: **http://www.usgcrp.gov/ or**
http://www.gcrio.org/agency.html

Information on the US government's research program on global change. Also provides access to the homepage of the International Panel on Climate Change (IPCC) which can also be accessed via http://www.usgcrp.gov/ipcc/.

NASA, Global Change Master Directory: **http://gcmd.gsfc.nasa.gov/**

Access to NASA and many other global change resources on the world wide web.

NOAA: **http://www.noaa.gov/**

NOAA is also involved in global change research. Mostly climate change and some water resources related data.

Human Dimensions Program (HDP): **http://www.ciesin.org/TG/HDP/HDPref.html**

The Human Dimensions of Global Environmental Change Program, created in 1990 by the International Social Science Council (ISSC), is an international and interdisciplinary program fostering activities that seek to describe and understand the human role in causing global environmental change and the consequences of these changes for society. Information on its activities and publications can be found at this site.

Human Dimensions of Global Change
Specialty Group of the AAG: **http://www.geog.utah.edu/~hdgcsg/index.html**

For an overview of the activities of the AAG Specialty Group on the Human Dimensions of Global Change, go to their homepage. It provides access to some of the resources mentioned above.

Appendix: Readings

The AAG was able to obtain reprint permission from the original publishers for only some of the readings suggested in the activities of this module. To avoid copyright problems, we suggest you make these readings available to your students by putting them on reserve. The following readings are enclosed:

1) FAO. 1970, 1980, 1991. *Production yearbook: Explanatory notes* and *Notes on tables*. FAO, Rome. (Reprinted with the permission of the FAO.)

2) Berg, B.L. 1995. "Chapter 2" in: *Qualitative research methods for the social sciences*. 2nd. ed., 14-28. Allyn and Bacon. Boston, MA. (Reprinted with the permission of Allyn & Bacon.)

3) Loveland, T.R. *et al.* 1995. Seasonal land-cover regions in the United States. *Annals, Association of American Geographers* 85: 339-355. (Reprinted with the permission of the AAG.)

Note: The excellent color map that came as a supplement with this issue of the *Annals* is available from the USGS for US$ 3 per map (at the time of publication) at the following address.

12201 Sunrise Valley Dr.
Mailstop 503
Reston, VA 22092

4) Rudel, T.K. 1989. Population, development, and tropical deforestation: A cross-national study. *Rural Sociology* 54, 3: 327-338. (Reprinted with permission.)

FAO. 1970. FAO Production Yearbook. Stats. Div.
of Economic and Social Policy Department.
FAO, Rome. 1971.

EXPLANATORY NOTES

Symbols

Definitions of symbols used in the tables:

*	Unofficial figure, except in the case of tables on population where * indicates United Nations estimate
—	None, in negligible quantity (less than one half of the unit indicated), or entry not applicable
...	Data not available
( )	Data not included in continental, regional, and world totals, either because they are components of a country total, or because they refer to a different series which is not to be included in the totals
F	FAO estimate

To divide the decimals from the whole number a period (.) is used.

In the case of computer-processed tables, a number placed at the left side of a country name indicates that an explanatory note can be found at the end of the table concerned. Also at the end of the table can be found the explanation of the abbreviations (denoted by one to five letters) placed under the name of the country.

Time reference

In the 1965 and earlier issues of the Yearbook, statistics on area and production of crops were presented on the basis of the split-year time reference period $n/n+1$, with the explanation that statistics for the Northern Hemisphere pertained generally to the harvests of the spring, summer and autumn of the year n, but for the more southerly regions of this hemisphere they represented harvests continuing into the early part of the following year $n+1$; and that for the Southern Hemisphere data related to crops generally harvested in the latter part of the year n and in the first part of the following year $n+1$. Detailed explanation on the adoption of this time reference policy was given in the Introduction to previous issues of the Yearbook.

As initiated in the 1966 edition of the Yearbook, the time reference policy is based on the calendar-year period. That is to say, the data for any particular crop refer to the calendar year in which the entire harvest or bulk of the harvest took place. Hence, the calendar-year annotation is used in the tables and the data of the countries are shown under these years according to this criterion.

There are a few exceptions to this general policy. The reference period for sugar, sugar beets, and sugarcane depends on the date on which the sugar campaign begins, and harvests and sugar production corresponding to the sugar campaign starting any time between March of the year n and February of the following year $n+1$ have been shown under the reference year $n/n+1$. Similarly, by long internationally accepted custom, the time reference for the cocoa crop is the period October to September, although one important producing country (Brazil) follows a different crop year.

It should also be noted that the adoption of a calendar-year time reference period inevitably means that, in a number of cases, crops assigned by countries to a particular split year may appear under different calendar years in the international tables.

With regard to livestock numbers, the dates of enumeration are specified for each country. They have been grouped into 12-month periods ending 30 September of the year stated. The statistics on livestock products are given for calendar years, unless otherwise specified.

For prices, the time reference of each annual average is indicated by showing the months included in the season at the head of each column of price data and entering the averages under the calendar year in which the beginning month of the season falls. In the case of wholesale, export and import prices, annual averages for many series have been calculated on the calendar-year rather than the split-year basis. Annual producer prices are compiled on a split-year basis, following, in most cases, national statistical practices. Thus the producer price statistics correspond to the production statistics entered in the Yearbook under the same calendar year.

The FAO index numbers of agricultural production have been calculated on the basis of a calendar-year reference period as defined above.

Crop areas

Figures for crop areas generally refer to harvested areas. In the tables on cereals, sugarcane, and tea, countries for which data are available only for sown area and not for harvested area are footnoted accordingly. For tables on grapes, abaca, agaves, and other hard fibres, the data shown generally refer to the planted area.

Yields per hectare

All yields per hectare for individual countries are computed from detailed production and area data. Yields for continental, regional, and world totals are computed from the totals shown.

Totals

Continental, regional, and world totals are shown for land use and population data, for crops (with a few exceptions), for major species of livestock, for meat, eggs, wool, cocoons (fresh) and raw silk production, as well as for fertilizers and tractors. China (mainland), if included in the body of the table, is shown below the total for Asia and is excluded from the Asia and Far East totals. Likewise, the figures for the U.S.S.R. are excluded from the total for Europe.

Following the same principle, the world total includes all countries listed in the table. In particular, China (mainland) and the U.S.S.R. are included in the world total if they are listed in the body of the table.

The geographical coverage of any total is thus explicitly indicated, enabling the reader to assess its adequacy. While every

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effort has been made to obtain as complete a coverage as practicable, there are a number of tables (on millets and sorghum, sweet potatoes and yams, cassava, pulses, fresh vegetables, fruit [except total grapes], rapeseed, buffalo, camels, fertilizers, and tractors) where, because of the paucity of information from the countries, the geographical coverage cannot be said to be complete.

One word may be added about country estimates not shown in the tables but included in the totals. These estimates are, in general, only rough estimates of orders of magnitude valid only for adjusting the totals. In some cases the totals have been further adjusted for deficient coverage within a country. For example, the official figure for meat production may refer only to inspected slaughter, but, wherever practicable, such figures have been inflated so as to correspond to full production in making up the continental, regional, and world totals. All such cases have been indicated in the relevant tables.

Averages

Averages in the crops and livestock tables refer generally to a period of five years. Two such averages are given for the periods 1948-52 and 1961-65.

As far as possible, these averages are computed from official data. When these were not available for the entire period, reliable unofficial estimates were used for the period not covered by official information; otherwise the average is limited to a number of years less than the full period.

Averages for continental, regional, and world totals are, however, always based on the full period, using, if necessary, estimates which allow for known trends for the missing years.

Notes on the tables and country notes

For a number of tables and countries the figures require more explanation and qualification than is possible here or in the footnotes to the individual tables. Explanation of these points, as well as other elements, including changes in territorial coverage, classification of countries by FAO regions, etc., are given in the Notes on the Tables and Country Notes at the end of the volume.

As a general rule, data in the Yearbook relate to the country specified with its present *de facto* boundaries. Country names and continental groupings follow, in general, the *Nomenclature of geographic areas for statistical purposes*, published by the Statistical Office of the United Nations, New York, 1 January 1949, taking into account subsequent revisions by that office.

The Notes on the Tables also include small tables giving statistical information on spelt, poppyseed, total fruit, nuts and vegetables, rock phosphate, and ground rock phosphate used for direct application. The information contained therein refers to selected countries only. An additional table shows livestock numbers, expressed in livestock units by continents and regions.

Conversion factors

The table of conversion factors on unit weight of selected commodities and countries has been included at the end of this volume, as in the previous issue of the Yearbook. For more detailed conversion factors the reader is referred to FAO's *Technical conversion factors for agricultural commodities*.

NOTES ON THE TABLES

LAND

Land use

This table is an attempt to bring together data on land use throughout the world. It should be borne in mind when considering this table that definitions used by reporting countries vary considerably and items classified under the same category often relate to greatly differing kinds of land. Furthermore, for a number of countries, data are either not available for certain land categories or are incomplete. Years shown in the table apply to columns 3 through 7.

In the compilation of the table, the following definitions were adopted:

1. *Total area* refers to the total area of the country, including area under inland water bodies.

2. *Land area* refers to total area, excluding area under inland water bodies. The definition of inland water bodies generally includes major rivers and lakes.

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3. *Arable land* refers to land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle. Within the scope of this definition there may be wide variation among reporting countries; the dividing line between temporary and permanent meadows, for instance, is rather indefinite; the period of time during which the unplanted land is considered fallow varies widely.

4. *Land under permanent crops* refers to land cultivated with crops which occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber; it includes land under shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber. A problem arises here as to whether bamboo, wattle, and cork oak plantations should be included under this heading or under forest land.

5. *Permanent meadows and pastures* refers to land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). Permanent meadows and pastures on which scattered trees and shrubs are grown should also be included in this category although some reporting countries include them under forests.

6. *Forest land* refers to land under natural or planted stands of trees, whether productive or not. It includes land from which forests have been cleared but which will be reforested in the foreseeable future. The question of savanna raises the same problem as in item 5.

7. *Other area* includes unused but potentially productive land, built-on area, wasteland, parks, ornamental gardens, roads, lanes, barren land, water bodies, and any other land not specifically listed under items 3 through 6.

For the first time, data for arable land and land under permanent crops have been broken down into two columns. However, because of the incomplete breakdown, it is not possible for the time being to calculate separate totals for each category.

In computing continental, regional, and world totals, estimates not shown in the table have been included for some countries when official data were lacking.

Among the changes in data shown in the previous editions of the Yearbook, those relating to Europe and North America are mostly due to actual changes in various land-use categories. For other continents, most of the changes reflect a general improvement in statistical information and in its interpretation for the classifications used in the table.

Irrigation

An attempt has been made in this table to bring together all available data on irrigated land throughout the world. Data relate to area purposely provided with water, including land flooded by river water, for crop production or pasture improvement, whether this area is irrigated several times or only once during the year stated.

It should be borne in mind that these figures are not internationally comparable since the definition of " irrigated land " varies widely from country to country and some countries report irrigated land under certain crops only. No attempt, therefore, has been made to compute continental, regional and world totals.

Number and area of agricultural holdings

Table 3 presents data on the number and area of holdings from the censuses taken within the framework of the 1960 World Census of Agriculture.

Generally, countries have used in their censuses FAO's concept of agricultural holding, that is, as consisting of all land which is used wholly or partly for agricultural production and is operated by one person — the holder — alone or with the assistance of others, without regard to title, size or location (livestock kept for agricultural purposes without agricultural land is also considered as constituting a holding). A number of countries, however, somewhat deviated from this definition by restricting the enumeration to those holdings which conformed to certain additional criteria and which fell above certain lower limits as to size of holding, or size of operation, or both. The more important modifications are explained in the footnotes to the table. They should be kept in mind when comparability between countries is envisaged.

Figures for holdings without land, shown separately, refer mainly to the establishments and units not possessing agricultural land but producing livestock or livestock products, e.g., piggeries, hatcheries, poultry batteries, city dairies with livestock, livestock kept by nomadic tribes, rabbitries, apiaries, etc.

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EXPLANATORY NOTES

FAO. 1980. FAO Production Yearbook, v. 34.
FAO Stats. Director of Economic and
Social Policy Department. FAO, Rome
1981.

Symbols

Definition of symbols used in the tables:

*	Unofficial figure
—	None, in negligible quantity (less than one half of the unit indicated), or entry not applicable. In the case of prices, no price quotation.
. . .	Data not available
AV	Average
F	FAO estimate
HA	Hectare
KG	Kilogram
KG/AN	Kilogram per animal
KG/HA	Kilogram per hectare
LB	Pound (avoirdupois)
MT	Metric ton
NES	Not elsewhere specified or included
ECU	European currency unit. Prior to 1979, meat prices for EEC are expressed in UA – unit of account (1 ECU = 1.209 UA)

In most of the tables a blank space has the same meaning as the symbols (—) or (. . .) defined above.

To divide decimals from whole numbers a full stop (.) is used.

Country and commodity names

In most of the tables the space provided for country and commodity names is limited to 12 and 24 letters respectively. The commodity names are given in English, French and Spanish; the names of continents, countries and regions in English only. While the abbreviated commodity names are sufficiently clear, the names of countries are at times somewhat obscure, and the reader should consult the List of Countries, Continents, Economic Classes and Regions (page 37), which shows the countries in the order in which they appear in the tables, providing abbreviated names in English and corresponding full names in English, French and Spanish.

Time reference

As initiated in the 1966 edition of the Yearbook, the time reference for statistics on area and production of crops is based on the calendar-year period. That is to say, the data for any particular crop refer to the calendar year in which the entire harvest or the bulk of it took place. This does not necessarily mean that, for a given commodity, production data are aggregated month by month from January to December, although this is true for certain crops such as tea, sisal, palm kernels, palm oil, rubber, coconuts, and, in certain countries, sugar cane and bananas, which are harvested almost uniformly throughout the year. The harvest of other crops, however, is generally limited to a few months and even, in certain cases, to a few weeks. Production of these crops is reported by the various countries in different ways: for calendar years, agricultural years, marketing years, etc. Whatever the statistical period used by the countries for presentation of area and production data, these data are allocated commodity by commodity to the calendar year in which the entire harvest or the bulk of it takes place. Obviously, when a crop is harvested at the end of the calendar year, production of this crop will be utilized mostly during the year following the calendar year under which production figures are shown in the tables.

It should be noted that the adoption of a calendar-year time reference period inevitably means that, in a number of cases, crops assigned by countries to a particular split year may appear under two different calendar years in the tables in this Yearbook.

Livestock numbers have been grouped in 12-month periods ending 30 September of the years stated in the tables, i.e., animals enumerated in a given country any time between 1 October 1978 and 30 September 1979 are shown under the year 1979.

As regards livestock products, data on meat, milk, and milk products relate to calendar years, with a few exceptions that are mentioned in the Notes on the Tables. Data for other animal products that are produced only in certain periods of the year, for example, honey and wool, are allocated to the calendar year, following a policy similar to that adopted for crops.

For tractors and other agricultural machinery, data refer, as far as possible, to the number in use at the end of the year stated or during the first quarter of the following year.

Data on pesticides are generally for the calendar year.

The FAO index numbers of agricultural production have been calculated on the basis of a calendar-year reference period as defined above.

Crop areas

Figures for crop areas generally refer to harvested areas, although for permanent crops data may refer to total planted area.

Yields per hectare

All yields per hectare, for single countries as well as for continental, regional, and world totals, are given in kilograms. In all cases they are computed from detailed area and production data, that is, hectares and metric tons. Data on yields of permanent crops are not as reliable as those for temporary crops, either because most of the area information may relate to planted area, as for grapes, or because of the scarcity and unreliability of the area figures reported by the countries, as for example for cocoa and coffee.

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Totals

Continental, regional and world totals are given for data on all commodities except those on pesticides and on milking machines. These totals include only data for the countries shown in the body of the table. Figures may not always add up to the totals given in the tables due to independent rounding of country figures and of the totals themselves. In general these totals reflect adequately the situation in the geographical areas they represent, with the exception of certain vegetable and fruit crops and certain livestock products. More details on this subject can be found in the Notes on the Tables.

Notes on the Tables and Country Notes

As a general rule, data in the Yearbook relate to the country specified with its present *de facto* boundaries. Country names and continental groupings follow, in general, the nomenclature used by the Statistical Office of the United Nations.

For a number of tables and countries the figures require more explanation and qualification than are possible here. Explanation of these points, as well as other elements, including changes in territorial coverage and classification of countries by FAO regions, are given below in the Notes on the Tables and the Country Notes.

NOTES ON THE TABLES

LAND

Land use and irrigation

These tables attempt to bring together all available data on land use and irrigated land throughout the world.

When considering the section on land use it should be borne in mind that definitions used by reporting countries vary considerably and items classified under the same category often relate to greatly differing kinds of land.

Definitions of land-use categories are as follows:

1. *Total area* refers to the total area of the country, including area under inland water bodies.

2. *Land area* refers to total area, excluding area under inland water bodies. The definition of inland water bodies generally includes major rivers and lakes.

3. *Arable land* refers to land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle.

The reader will notice significant changes in the arable land of some African countries. This is due to the exclusion of large areas of what is considered by these countries as fallow land resulting from shifting cultivation.

4. *Land under permanent crops* refers to land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber; it includes land under shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber.

5. *Permanent meadows and pastures* refers to land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

6. *Forests and woodland* refers to land under natural or planted stands of trees, whether productive or not, and includes land from which forests have been cleared but that will be reforested in the foreseeable future.

7. *Other land* includes unused but potentially productive land, built-on areas, wasteland, parks, ornamental gardens, roads, lanes, barren land, and any other land not specifically listed under items 3 through 6.

Data on irrigation relate to areas purposely provided with water, including land flooded by river water for crop production or pasture improvement, whether this area is irrigated several times or only once during the year stated.

Specific country notes pertaining to land-use categories and irrigation are given below.

TOTAL AREA

Greenland: Data refer to area free from ice.

Mauritius: Data exclude dependencies.

Namibia: Data include the territory of Walvis Bay.

New Caledonia: Data include dependencies.

South Africa: Data exclude the territory of Walvis Bay.

USSR: Data include the White Sea (9 000 000 hectares) and the Azov Sea (3 730 000 hectares).

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ARABLE LAND AND LAND UNDER PERMANENT CROPS

Australia: Data on arable land include about 27 000 000 hectares of cultivated grassland.

Cuba: Data refer to the State sector and to entailed land only.

Germany, Federal Republic of: Data include arable land and land under permanent crops on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

Portugal: Data include about 800 000 hectares of temporary crops grown in association with permanent crops and forests.

PERMANENT MEADOWS AND PASTURES

Australia: Data refer to balance of area of rural holdings.

Egypt: Rough grazing land is included under Other land.

Germany, Federal Republic of: Data include permanent meadows and pastures on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

USSR: Data exclude pastures for reindeer.

For the following countries, data refer to permanent meadows and pastures on agricultural holdings only: *Chile, Dominican Republic, Finland, Guatemala, Suriname, Trinidad and Tobago Uruguay.*

FORESTS AND WOODLAND

Germany, Federal Republic of: Data include forests and wood land on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

IRRIGATION

Hungary: Data exclude complementary farm plots and individual farms.

United Kingdom: Data exclude those for Scotland and Northern Ireland.

For all the following countries data refer to land provided with irrigation facilities: *Bulgaria, Denmark, France, Romania, Suriname.*

Sri Lanka: Data refer to irrigated rice only.

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EXPLANATORY NOTES

FAO. 1991. FAO Production Yearbook, v. 45.
Basic Data Unit, Stats. Division.
FAO, Rome. 1992.

Symbols

Definition of symbols used in the tables:

*	Unofficial figure
—	None, in negligible quantity (less than one half of the unit indicated), or entry not applicable. In the case of prices, no price quotation
…	Data not available
AV	Average
F	FAO estimate
HA	Hectare
KG	Kilogram
KG/AN	Kilogram per animal
KG/HA	Kilogram per hectare
LB	Pound (avoirdupois)
MT	Metric ton
NES	Not elsewhere specified or included
ECU	European currency unit

In most of the tables, a blank space has the same meaning as the symbols (—) or (...) defined above.

To divide decimals from whole numbers, a full stop (.) is used.

Country and commodity names

In most of the tables, the space provided for country and commodity names is limited to 12 and 24 letters respectively. The commodity names are given in English, French and Spanish; the names of continents, countries and regions in English only. While the abbreviated commodity names are sufficiently clear, the names of countries are at times somewhat obscure, and the reader should consult the List of Countries, Continents, Economic Classes and Regions (page xlv), which shows the countries in the order in which they appear in the tables, providing abbreviated names in English and corresponding full names in English, French and Spanish.

Time reference

As initiated in the 1966 edition of the yearbook, the time reference for statistics on area and production of crops is based on the calendar-year period. That is to say, the data for any particular crop refer to the calendar year in which the entire harvest or the bulk of it took place. This does not necessarily mean that, for a given commodity, production data are aggregated month by month from January to December, although this is true for certain crops such as tea, sisal, palm kernels, palm oil, rubber, coconuts, and, in certain countries, sugar cane and bananas, which are harvested almost uniformly throughout the year. The harvest of other crops, however, is generally limited to a few months and even, in certain cases, to a few weeks. Production of these crops is reported by the various countries in different ways: for calendar years, agricultural years, marketing years, etc. Whatever the statistical period used by the countries for presentation of area and production data, these data are allocated commodity by commodity to the calendar year in which the entire harvest or the bulk of it takes place. Obviously, when a crop is harvested at the end of the calendar year, production of this crop will be utilized mostly during the year following the calendar year under which production figures are shown in the tables.

It should be noted that the adoption of a calendar-year time reference period inevitably means that, in a number of cases, crops assigned by countries to a particular split year may appear under two different calendar years in the tables in this yearbook.

Livestock numbers have been grouped in 12-month periods ending 30 September of the years stated in the tables, e.g. animals enumerated in a given country any time between 1 October 1990 and 30 September 1991 are shown under the year 1991.

As regards livestock products, data on meat, milk, and milk products relate to calendar years, with a few exceptions that are mentioned in the Notes on the Tables. Data for other animal products that are produced only in certain periods of the year, for example, honey and wool, are allocated to the calendar year, following a policy similar to that adopted for crops.

For tractors and other agricultural machinery, data refer, as far as possible, to the number in use at the end of the year stated or during the first quarter of the following year.

Data on pesticides are generally for the calendar year.

The FAO index numbers of agricultural production have been calculated on the basis of a calendar-year time reference period as defined above.

Crop areas

Figures for crop areas generally refer to harvested areas, although for permanent crops data may refer to total planted area.

Yields per hectare

All yields per hectare, for single countries as well as for continental, regional, and world totals, are given in kilograms. In all cases, they are computed from detailed area and production data, that is, hectares and metric tons. Data on yields of permanent crops are not as reliable as those for temporary crops either because most of the area information may relate to planted area, as for grapes, or because of the scarcity and unreliability of the area figures reported by the countries, as for example for cocoa and coffee.

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ARABLE LAND AND LAND UNDER PERMANENT CROPS

Australia: Data on arable land include about 27 000 000 hectares of cultivated grassland.

Cuba: Data refer to the State sector and to entailed land only.

Germany, Federal Republic of: Data include arable land and land under permanent crops on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

Portugal: Data include about 800 000 hectares of temporary crops grown in association with permanent crops and forests.

PERMANENT MEADOWS AND PASTURES

Australia: Data refer to balance of area of rural holdings.

Egypt: Rough grazing land is included under Other land.

Germany, Federal Republic of: Data include permanent meadows and pastures on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

USSR: Data exclude pastures for reindeer.

For the following countries, data refer to permanent meadows and pastures on agricultural holdings only: *Chile, Dominican Republic, Finland, Guatemala, Suriname, Trinidad and Tobago, Uruguay.*

FORESTS AND WOODLAND

Germany, Federal Republic of: Data include forests and woodland on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

IRRIGATION

Hungary: Data exclude complementary farm plots and individual farms.

United Kingdom: Data exclude those for Scotland and Northern Ireland.

For all the following countries data refer to land provided with irrigation facilities: *Bulgaria, Denmark, France, Romania, Suriname.*

Sri Lanka: Data refer to irrigated rice only.

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Totals

Continental, regional and world totals are given for data on all commodities except those on pesticides and on milking machines. The totals include only data for the countries shown in the body of the table. Figures may not always add up to the totals given in the tables due to independent rounding of country figures and of the totals themselves. In general, these totals reflect adequately the situation in the geographical areas they represent, with the exception of certain vegetable and fruit crops and certain livestock products. More details on this subject can be found in the Notes on the Tables.

Notes on the Tables and Country Notes

As a general rule, data in the yearbook relate to the country specified with its present *de facto* boundaries. Country names and continental groupings follow, in general, the nomenclature used by the Statistical Office of the United Nations.

For a number of tables and countries, the figures require more explanation and qualification than are possible here. Explanation of these points, as well as other elements, including changes in territorial coverage and classification of countries by FAO regions, are given below in the Notes on the Tables and the Country Notes.

NOTES ON THE TABLES

LAND

Land use and irrigation

These tables attempt to bring together all available data on land use and irrigated land throughout the world.

When considering the section on land use, it should be borne in mind that definitions used by reporting countries vary considerably and items classified under the same category often relate to greatly differing kinds of land.

Definitions of land-use categories are as follows:

1. *Total area* refers to the total area of the country, including area under inland water bodies. Data in this category are obtained from the United Nations Statistical Office, New York.

2. *Land area* refers to total area, excluding area under inland water bodies. The definition of inland water bodies generally includes major rivers and lakes.

3. *Arable land* refers to land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow (less than five years).
   The abandoned land resulting from shifting cultivation is not included in this category.

4. *Land under permanent crops* refers to land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber; it includes land under shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber.

5. *Permanent meadows and pastures* refers to land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). The dividing line between this category and the category "Forests and woodland" is rather indefinite, especially in the case of shrubs, savannah, etc., which may have been reported either under one or the other of these two categories.

6. *Forests and woodland* refers to land under natural or planted stands of trees, whether productive or not, and includes land from which forests have been cleared but that will be reforested in the foreseeable future. The question of shrub land, savannah, etc., raises the same problem as that in the category "Permanent meadows and pastures".

7. *Other land* refers to any other land not specifically listed under items 3 through 6. It includes built-on areas, roads, barren land, etc.

Data on irrigation relate to areas purposely provided with water, including land irrigated by controlled flooding.

Specific country notes pertaining to land-use categories and irrigation are given below.

TOTAL AREA

Greenland: Data refer to area free from ice.

Mauritius: Data exclude dependencies.

Former USSR: Data include the White Sea (9 000 000 hectares) and the Azov Sea (3 730 000 hectares).

ARABLE LAND AND LAND UNDER PERMANENT CROPS

Australia: Data on arable land include about 27 000 000 hectares of cultivated grassland.

Cuba: Data refer to the State sector and to entailed land only.

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Former USSR: Data exclude pastures for reindeer.

FORESTS AND WOODLAND

Germany, Federal Republic of: Data include forests and woodland on holdings of 1 hectare and above, and on holdings of less than 1 hectare whose production market value exceeds a fixed minimum.

IRRIGATION

Cuba: Data refer to State sector only.

Denmark, Romania: Data refer to land provided with irrigation facilities.

Hungary: Data exclude complementary farm plots and individual farms.

Japan, Korea, Republic of, Sri Lanka: Data refer to irrigated rice only.

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Berg, B.L. 1995. *Qualitative Research Methods for the Social Sciences.* Allyn & Bacon: Boston.

2

DESIGNING QUALITATIVE RESEARCH

THIS CHAPTER CONSIDERS VARIOUS ways of thinking about and designing research. It includes a discussion of the relationships among ideas and theory, concepts, and what I have long believed is the most difficult facet of research—namely, operationalization. This chapter further offers a strategy for conducting literature reviews and explains the importance of carefully designing and planning research in advance. Let's begin with some thoughts about ideas and theory.

IDEAS AND THEORY

Every research project has to start somewhere. Typically, this starting point is an idea. Sometimes this idea originates because of a particular problem or situation one actually experiences. For example, a nurse might observe a coworker coming to work under the influence of alcohol and begin to think about how that influences nursing care. From this thought, the idea for researching impaired nurses could arise. A counselor at a delinquency detention center might notice that many of her clients have been battered or abused prior to their run-ins with the law. From this observation, she might begin to think about how abuse might be linked with delinquency and how she could investigate this linkage. Or an elementary school teacher might notice that the most disruptive children in the class eat large amounts of sugary junk food during lunch. The teacher might begin to think about the possibility that junk food is in some way related to children's behavior and might wonder how he or she could test such an idea.

In some situations, ideas move from information you hear but may not actually experience yourself. For instance, you're sitting at home listening to the news, and you hear a report about three youths from wealthy families who have been caught burglarizing houses. You begin to wonder, Why on earth do they do something like that? What motivates people who don't need money to steal from others? Or you read in the newspaper that a man living around the corner from you has been arrested for growing marijuana in his garage. You start thinking back to times when you passed this man's house and smiled a greeting at him. Or you begin to wonder, Why didn't I realize what he was up to? Who was he going to sell the marijuana to, anyhow? From these broad curiosities, you might begin to think about how these questions could be explored or answered, how you might research these phenomena.

The preceding examples serve two important purposes. First, they point out how ideas promote potential research endeavors. But second, and perhaps more important, they suggest a central research orientation that permeates this book. This orientation is the attitude that the world is a research laboratory, that you merely need to open your ears and eyes to the sensory reality that surrounds all of us to find numerous ideas for research. In fact, once you become familiar with this orientation, the biggest problem will be to filter out all the many possible researchable ideas and actually investigate one!

So, you begin with an idea. But how is this related to theory? For that matter, what is meant by theory? In a formal sense, social scientists usually define *theory* as a system of logical statements or propositions that explain the relationship between two or more objects, concepts, phenomena, or characteristics of humans—what are sometimes called *variables* (Babbie, 1992; Denzin, 1978; Polit & Hungler, 1993). *Theory* might also represent attempts to develop explanations about reality or ways to classify and organize events, describe events, or even to predict future occurrences of events (Hagan, 1993).

There are some who argue that ideas and theory must come before empirical research. This has been called the *theory-before-research model* (Nachmias & Nachmias, 1992, p. 46). This orientation has been nicely described by Karl Popper (1968), who suggests that one begins with ideas (conjectures) and then attempts to disprove or refute them through tests of empirical research (refutation).

In contrast to the theory-before-research proponents, there are some who argue that research must occur before theory can be developed. This orientation, *research-before-theory*, can be illustrated by a statement from Robert Merton (1968, p. 103):

> *It is my central thesis that empirical research goes far beyond the passive role of verifying and testing theory; it does more than confirm or refute hypotheses.*

> *Research plays an active role: it performs at least four major functions which help shape the development of theory. It initiates, it reformulates, it deflects, and it clarifies theory.*

In other words, research may suggest new problems for theory, require theoretical innovation, refine existing theories, or serve to verify past theoretical assumptions.

The approach offered in this book views theory-before-research and research-before-theory as highly compatible. Often, methods texts and courses describe the research enterprise as a linear progression. In this progression, you begin with an idea, gather theoretical information, design a research plan, identify a means for data collection, analyze the data, and report findings. This may be diagramed as follows:

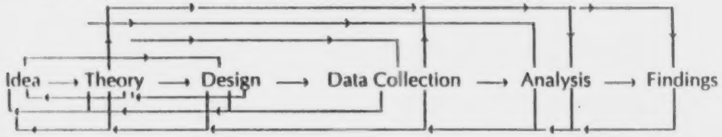
Idea → Theory → Design → Data Collection → Analysis → Findings

For the most part, this orientation resembles the theory-before-research model. But it could also be drawn as the research-before-theory model:

Idea → Design → Data Collection → Theory → Analysis → Findings

In either case, you have the feeling that each of these components is a distinct and separate successive stage, that you first derive an idea, then move on to either theory or design, and so forth. In essence, it seems that you complete various necessary tasks of each stage and then move forward, leaving the completed state behind.

In this chapter, I argue for a different model for the research enterprise, a model that encompasses both the research-before-theory and theory-before-research models. This is possible because the proposed approach is conceived as spiraling rather than linear in its progression. In the proposed approach, you begin with an idea, gather theoretical information, reconsider and refine your idea, begin to examine possible designs, reexamine theoretical assumptions, and refine these theoretical assumptions and perhaps even your original or refined idea. Thus, with every two steps forward, you take a step or two backward before proceeding any further. What results is no longer a linear progression in a single, forward direction. Rather, you are spiraling forward, never actually leaving any stage behind completely. This spiraling approach may be drawn as follows:



In order to make things easier to follow as individual elements of this model are discussed, let's redefine the stages slightly, as follows:

Idea → Literature Review → Design → Data Collection and Organization → Analysis and Findings → Dissemination

As shown above, you begin with some rough *idea* for a research study. The next stage in this process is to begin thinking and reading about this topical idea. This is accomplished as you begin the literature review.

LITERATURE REVIEW

After developing a rough idea for research, you begin to examine how others have already thought about and researched the topic. Let's say an idea for some research begins with an interest in alcohol use by male college students. You might formulate a rough question for research, such as: What is the relationship between college and drinking among American males? This rough statement already shows elements of refinement. It has been limited to consideration only of American males. The next step is to visit the library to get started on a literature review. To begin, you can consult any of a number of available cumulative indexes. These indexes contain many thousands of journal and monograph references, indexed by both authors' names and subject topics. In some cases, you will find these as bound texts in the reference section of the library. In other cases, these indexes may be computer based and require both some assistance and a small charge to use.

In many larger public libraries and in a growing number of colleges and universities, these cumulative indexes have been placed in CD-ROM format. If you have never used one of these indexes or are unfamiliar with the use of computers, you might want to consult the reference librarian at your library.

The next task is to begin to creatively think about cryptic subject topics related to your rough research idea or question and to search for these topics in the indexes. For the example above, you might begin making a list, such as "alcohol use," "collegiate alcohol use," "alcohol on campus," "drinking," "males and alcohol," "Americans and alcohol," "social drinking," "substance abuse in college," "campus problems," and so forth. It is important to develop a number of different subject areas to search. Some will be more fruitful than others, and perhaps some will yield little information. This is because both the paperbound versions and computer-based versions of indexes are created by humans! Because of this, they unavoidably suffer from the problem of terminological classification bias. In other words, even though these indexes are cross referenced, if you do not use the same term or phrase used by the original indexer, you may not locate entries he or she has referenced.

For instance, several years ago, I became interested in the idea of doing research about women in policing. More directly, I was interested in the effect of policing on female officers. I asked my graduate student to see if she could locate some material about female police officers. When she returned the next day, she reported that there was virtually nothing in any of the index data bases on the topic "female police officers." I asked if she had tried "women in policing," or "women police officers," or even "minorities in policing." Sheepishly, she explained she had not thought to do that and returned to the library. The next time she returned to my office, she carried a list of literally dozens of references for me to consider. The lesson to be learned from this is that you must not be too restrictive in your topics when searching for reference materials in indexes. In fact, most CD-ROM-based indexes provide users with a thesaurus to assist them in locating subject terms used to index material on the CD-ROM.

You have located the relevant reference indexes for the research idea and have used cryptic subject terms to locate a list of references. The next task is to locate several of these pieces of literature and begin reading about the topic. You also will need to continue trying to expand this literature search. You can do this by locating several fairly recent articles and consulting their reference pages. Frequently, this search will yield additional pieces of information that were not generated by the original index search.

As you are doing all this literature searching, it is advisable for you to keep records on which pieces of literature you have obtained and notes about what each one says. There are numerous ways you can keep records and notes during a literature review. What follows, the *two-card method*, is a long-standing albeit very time-consuming strategy. Inexperienced writers and researchers may want to try using it fairly precisely. More experienced investigators may decide to make variations on it. In any event, it provides a means for developing an extremely systematic literature review.

The Two-Card Method

As indicated by the name, this strategy requires you to create two types of 4 x 6-inch index cards. The first is the *author card*. Annotate each with the reference information for every article of literary material you locate and examine. Whenever possible, you should also include the library call numbers. Several of my students in recent years have preferred to use electronic index cards, as provided in some computer software packages. Although any entry format on the card or electronic card can be used, I recommend that you use a consistent entry style. (See Figure 2–1.)

```
[Author's Name]
 Berg, Bruce L.,

     [Date]      [Title of document and publication
      1992        information]

                  Law Enforcement: An Introduction to
                  Police in Society. Boston, Mass.:
                  Allyn and Bacon

[Library Call #]
```

FIGURE 2–1 Author Card

Author cards should be kept in alphabetical order to ensure that you always will have complete information for citations and the ability to locate the document at a later time. Even fairly experienced writers have misplaced a document or returned it to the library, only to find they need it or the citation material later. Often, even with considerable effort, these writers are unable to locate the necessary information. Author cards provide a kind of insurance against not having the correct information when you need to write up references or check up on information. As well, should you continue researching in this area, you will have a head start on future literature reviews.

The second type of card is called the *topic card*. Topic cards also should follow a consistent pattern and include the author's name, the date of the publication, a brief topical label, and a short verbatim excerpt. Since the authors cards contain all the title and publication information, it is not necessary to duplicate those details on the topic cards. (See Figure 2–2.)

```
           [Topic Label]  Police Detective
 [Author's Name]
  Berg, Bruce (1992:p83)

       [Verbatim Quote]

Detective, as a noun, makes its first appearance in lay
parlance in the 1840s in order to identify the police
organizational position of an investigator (Klockars,
1985, Kuykendal, 1986, 175). The central function of
early detective work in police organizations was
```

FIGURE 2–2 Topic Card

Many students have either been taught or have developed similar note-taking strategies. In some cases, these other strategies call for the use of legal-length note pads. This technique, however, inhibits your ability to sort through or organize the excerpts, short of cutting sheets into pieces. Additionally, these other strategies usually ask you to paraphrase the material you take down as notes. Certainly, paraphrasing is somewhat less tedious to accomplish than the verbatim annotation of excerpts, as promoted in my plan. However, there are several critical reasons why I recommend the use of verbatim quotes on these topic cards.

First, it reduces the physical amount of material you will ultimately use when you get down to writing reports about the research. Anyone who has undertaken a large writing project, even a term paper, should relate to the problem of having stacks of photocopies and piles of books cluttering the room. Trying to find some specific piece of information under such circumstances is quite burdensome.

Second, you can very quickly sort the topic cards into their categories (e.g., placing all the cards about police detectives together). In this manner, you can assemble the piles into an organized sequence reflecting how you will write the report or paper. This allows you to read through the relevant materials for each section rather than repeatedly reading through all the material in order to write a single section.

Third, topic cards allow you to assess whether multiple authors actually have made similar statements about issues or situations. In turn, you are able to make strong synthesized statements regarding the work or arguments of others. For example, "According to Babbie (1992), Nachmias and Nachmias (1993), and Leedy (1993), design is a critically important element in the development of a research project."

If you, as an investigator, paraphrase material on the topic cards, it is possible that you might slant or alter meanings. Without intending to, you might have misread, misinterpreted, or poorly paraphrased material. When you go through the topic cards looking for agreement among authors, you might find paraphrased statements that *seem* to represent similar ideas but that actually do not accurately represent the sentiments of the original authors. Using verbatim excerpts ensures that this will not occur. Either the authors did say similar things or they did not.

The obvious question at this juncture is, How much should you annotate on the topic cards? While there are no hard and fast rules, I recommend only about two to four paragraphs. The purpose of these cards is to reduce the amount of material ultimately necessary for the writer-investigator. To completely transcribe works tends to defeat this purpose. Bear in mind that you might find three or four different topics in a short article, or you might find six or seven. Likewise, you might find ten or twelve topics to excerpt in a book, or you might find only a single topic worthy of excerpting.

Usually the excerpt will fit on a single card (front and back). However, on occasion, you might find it necessary to use a second or even a third card. It is important to number or letter subsequent cards in order to keep them in correct sequence. In the event that you find an enormous cache of simply wonderful material, you can make a note of this on the card. This is a better strategy than copying 10 or 11 cards. Simply excerpt the usual three or four paragraphs, then write something like "MORE GREAT MATERIAL!" In this case, you will want to have the source nearby when you write the paper.

Excerpting for topic cards can be fairly tedious. You should not plan on spending many hours at a time writing topic cards. Instead, plan to spend only an hour or so at each topic card writing session. Even small amounts of time, such as 10- or 15-minute intervals, can be successfully used for this purpose. Remember, what this strategy loses in excitement it gains tenfold in organization and effective writing later.

This strategy also is very portable. You can slip index cards into your pocket, bag, briefcase, or backpack along with a book or photocopy of some article. While waiting for a doctor's or dentist's appointment, you can easily be reading and excerpting material. Or you might do topic cards while riding a train or bus. The important thing to remember is that as you are reading and creating topic cards, you also should be thinking about the material.

Thoughts should begin to turn toward refinements of the original research idea or question. What are some specific research questions that need to be considered in the eventual research? How have others theorized about the topic? How have others researched the topic? What have others found in previous research? Is there an interesting angle or approach that would set your research apart from that of others or refine findings offered by past research? You also should begin to consider exactly how *you* will frame your research questions or problems.

FRAMING RESEARCH PROBLEMS

Research problems direct or drive the research enterprise. *How* you will eventually conduct a research study depends largely upon *what* your research questions are. It is important, therefore, to frame or formulate a clear research problem statement. Remember, the research process began with an idea and only a rough notion of what was to be researched. As you read and collect information from the literature, these rough questions must become clearer and theoretically more refined.

Let's return to our original research idea: What is the relationship between college and drinking among American males? After reading through some of the literature, you might begin to refine and frame this idea as a problem statement with researchable questions:

Problem Statement
This research proposes to examine alcohol drinking behaviors in social settings among college-age American men.

Research Questions
A number of questions are addressed in this research including (although not limited to) the following:

1. What are some normative drinking behaviors of young adult American men during social gatherings where alcohol is present?
2. How do some young adult American men manage to abstain from drinking (e.g., avoidance rituals) while in social situations where alcohol is present?
3. How do young adult American men define appropriate drinking practices?
4. How do young adult American men define alcoholism?

These questions did not just happen spontaneously. They were influenced by the literature about drinking practices among Americans. They resulted after the investigator began thinking about what issues were important and how those issues might be measured. This required the researcher to consider various concepts and definitions and perhaps to develop operationalized definitions.

OPERATIONALIZATION AND CONCEPTUALIZATION

When someone says, "That kid's a delinquent," most of us quickly draw some mental picture of what that is, and we are able to understand the meaning of the term *delinquent*. If, however, someone were to ask, "How would you define a delinquent?" we would probably find that some people think about this term differently than others. For some, it may involve a youth under the legal age of adult jurisdiction (usually between 16 and 18 years of age) who commits law violations (Bynum & Thompson, 1992). For others, a delinquent may be simply defined as a youthful law violator (Thornton & Voigt, 1992). Still others may require in their definition some notion of a youth who not only breaks a law but who is also convicted in court of this law violation (Siegel & Senna, 1988). In other words, there are a number of possible definitions for the concept *delinquent*.

If you, as a researcher, are interested in studying the behavior of delinquent girls, you will first need to clearly define *delinquent*. Because humans cannot telepathically communicate their mental images of terms, there is no way to directly communicate which possible meaning for delinquent you have in mind. To ensure that everyone is working with the same definition and mental image, you will need to *conceptualize* and *operationalize* the term. This process is called *operationally defining* a concept.

Operational definitions concretize the intended meaning of a concept in relation to a particular study and provide some criteria for measuring the empirical existence of that concept (Leedy, 1993; Nachmias & Nachmias, 1992).

In operatively defining a term or concept, you, as a researcher, begin by declaring the term to mean whatever you want it to mean throughout the research. While it is important for your readers to understand what you mean when, for example, you use the concept *delinquent*, they need not necessarily agree with that definition. As long as they understand what you mean by certain concepts, they can understand and appraise how effectively the concept works in your study.

Once defined, the concept needs some way to be measured during the research process. In quantitative research, this means creating some index, scale, or similar measurement indicator intended to calculate how much of or to what degree the concept exists. Qualitative investigators also need agreement over what a concept means in a given study and how that concept is to be identified and examined. How will the researcher gather empirical information or data that will inform him or her about the concept?

Consider, for example, the concept *weight*. As a researcher, you might define the concept *weight* as the amount of mass an object possesses in terms of pounds and ounces. Now everyone holds the same concrete meaning and mental image for the concept weight. How shall this concept be measured? Operationally, weight can be determined by placing an object on a scale and rounding to the nearest ounce. This operational definition clearly tells others what the concept is designated to mean and how it will be measured.

Unfortunately, not all concepts are as easy to define as weight or as easy to measure. Polit and Hungler (1993), for example, suggest that many concepts relevant to research in nursing are not operationalized simply. For instance, in nursing research, the quality of life for chronically ill patients may be defined in terms of physiological, social, and psychological attributes. If the nurse researcher emphasizes the physiological aspects of quality of life for chronically ill patients in his or her definition, the operationalized component may involve measuring white blood cell counts or oxygen output, assessing invasive surgical procedures or ventilation procedures, measuring blood pressure, and so forth.

If, on the other hand, quality of life for chronically ill patients is defined socially, the operationalized elements of the definition would need to measure family or social support, living arrangements, self-management skills, independence, and similar social attributes. Likewise, if the nurse researcher uses a more psychological conceptualization, the operationalized measures would be directed along the lines of the patients' emotional acceptance of chronic illness.

Let's try another illustration of defining and operationalizing. Say you are interested in studying to what degree or extent people are religious. To begin, you must define the concept *religious*. For this example, *religious* will be defined as how actively one is involved with his or her religion. Next, you must decide what kinds of information inform others about someone's active involvement in religion. After consulting the literature, you decide that you know how religious someone is by knowing whether someone believes in a divine being, attends organized religious services on some regular basis, prays at home, reads religious materials, celebrates certain religious holidays, readily declares membership in a particular religion, participates in religious social organizations, and contributes to religious charities.

In effect, you, the researcher, are saying, "I can't immediately apprehend a person's religiousness. But I can think about what elements seem to go into making up or representing observable behaviors I understand to mean *religious*." By obtaining information regarding the subset of observable attributes delineated above to represent religious, you can study religiousness. Again, as you are thinking about what observable attributes might make up some concept, you should be perusing the literature. By spiraling back into the literature stage, you can seek ways others have previously examined the concept of religious. You may borrow some of these previous attributes for religious, or you may create others.

In some forms of qualitative research, the investigator is not as rigorously concerned with defining concepts in operational terms as outlined here. This is because some forms of interpretative and phenomenological research seek to discover naturally arising meanings among members of study populations. However, in many cases of qualitative research, failure to define and operationalize concepts will spell disaster. If, as a researcher, you have not made clear what your concepts mean, your results may be meaningless in terms of explanatory power or applicability. If you have not thought about how data will be collected to represent attributes of the concept, it will be very difficult for you to determine answers to research questions. And if you have not worked with the literature in developing relevant meanings and measurable attributes, it will be impossible for you to see how eventual results fit into this extant body of knowledge.

Your next problem, then, is determining exactly how information about various attributes will be obtained. As you reach this point, you move one foot forward to the design stage of the research enterprise. Naturally, one foot will remain in the literature stage.

DESIGNING PROJECTS

The design for a research project is literally the plan for how the study will be conducted. It is a matter of thinking about, imagining, and visualizing

how the research study will be undertaken (DeBakey & DeBakey, 1978; Leedy, 1993).

The design stage of research is concerned with what types of information or data will be gathered and through what forms of data-collection technology. In doing research, you must decide whether to use one data-collection strategy alone or combine several (data triangulation). Will you undertake the study alone or with the assistance of others (multiple investigators triangulation)? You must consider whether the study will be framed by a single overarching theory or by several related theories (theoretical triangulation). How much will the project cost in time and money, and how much can you actually afford? What population will best serve the study's purposes? Are the data-collection strategies appropriate for the research questions being asked? What will the data look like once they have been collected? How will the data be organized and analyzed?

In effect, during the design stage, you, the investigator, sketch out the entire research project in an effort to foresee any possible glitches that might arise. If you locate a problem now, while the project is still on the drafting board, there is no harm done. After the project has begun, if you find that concepts have been poorly conceived, that the wrong research questions have been asked, or that the data collected are inappropriate, the project may be ruined.

Researchers in the social sciences typically conduct research on human subjects. It is during the design stage that you, the researcher, must consider whether ethical standards and safeguards for subject safety are adequate; you must make certain that subjects will be protected from any harm. Chapter 10 discusses issues of research ethics in detail. For now, it should suffice to say that during the design stage, you appraise ethical proprieties such as honesty; openness of intent; respect for subjects; issues of privacy, anonymity, and confidentiality; the intent of the research; and the willingness of subjects to participate voluntarily in the research.

DATA COLLECTION AND ORGANIZATION

As you begin visualizing how the research project will "unfold, cascade, roll, and emerge" (Lincoln & Guba, 1985, p. 210), you also must imagine what the data will look like. Will raw data be audiotape cassettes resulting from lengthy depth interviews? Will data comprise dozens of spiral notebooks filled with field notes? Will they include photographs or video recordings? Will they entail systematic observational checklists or copies of files containing medical or criminal histories? May data actually be the smudges left on a polished counter or glass display case? Just what will the research data look like?

Furthermore, what will you do with the data to organize them and make them ready for analysis? It is interesting to note that even after taking several research courses, many students fall down at this stage of the research process and find themselves lost. While most research courses and textbooks are excellent at describing the basic structure of research, few move the student into the areas of data organization and analysis. What results are students who can come up with excellent ideas for research, conduct solid literature reviews, produce what sound like viable research designs, and even collect massive amounts of data. The problem arises, however, at this point: What do they do with this mountain of data once it has been collected?

If you were doing quantitative research, there might be an easy answer to the question of organization and analysis. You would reduce the data to computerizable form and enter them into a data base. Then using one form or another of packaged statistics for the social sciences, you would endeavor to analyze the data. Lamentably, qualitative data are not as quickly or easily handled. A common mistake made by many inexperienced or uninformed researchers is to reduce qualitative data to symbolic numeric representations and quantitatively computer analyze them. As Berg and Berg (1993) state, this ceases at once to be qualitative research and amounts to little more than a variation of quantitative data collection.

How qualitative data are organized depends in part upon what they look like. If they are in textual form, such as field notes, or can be made into textual form, such as a transcription of a tape-recorded interview, they may be organized in one manner. If they are video, photographic, or drawn material, they will require a different form of organization and analysis. But regardless of the data form, you must consider this issue during the design stage of the process. Again, this points to the spiraling effect of research activities. If you wait until data have actually been collected to consider how they are to be organized for analysis, serious problems may arise. For example, you may not have planned for adequate time or financial resources. Or you might collect data in such a way that they should be systematically organized, coded, or indexed as they were collected and not after the fact. In any event, you must direct thought toward how data will be organized and analyzed long before you begin the data-collection process. Specific issues related to various aspects of data organization and analysis of qualitative data are discussed throughout this book.

DISSEMINATION

Once the research project has been completed, it is not really over. That is, doing research for the sake of doing it offers no benefit to the scientific community or to the existing body of knowledge it might inform. Research, then, is not complete until it has been disseminated. This may be accomplished though reports submitted to appropriate public agencies or to funding sources. It may include informal presentations to colleagues at brown-bag lunches or formal presentations at professional association meetings. It may involve publishing reports in one of a variety of academic or professional journals. Regardless of how the information is spread, it must be disseminated if it is to be considered both worthwhile and complete. Chapter 11 explains how you may go about disseminating your research results. For the purposes of designing research projects, it is important to bear in mind that this stage of the research process is integral to the whole.

TRYING IT OUT

There are a number of ways you can practice aspects related to the planning of research. Below are only a few suggestions that should allow you an opportunity to gain some experience. While these are useful experiential activities, they should not be confused with actually conducting research.

Suggestion 1

Locate three or four different textbooks on juvenile delinquency. Look up the definition of *delinquent* either in the text or in the glossary. Remember, you might need to try looking under "juvenile delinquent," depending on how the term was indexed. Now consider the differences, if any, that exist between each text's definition, and write a single synthesized definition.

Suggestion 2

Locate the *Index to the Social Sciences* in a college or university library. Use this index to find 10 sources of reference material for a potential study on child abuse. Remember to be creative in developing topics to look up.

Suggestion 3

Identify six concepts and operationally define each. Be sure to consult relevant literature before terms are defined. Do not just make up definitions. When operatively defining how each concept will be measured, be certain these operations conform to both relevant literature and the qualitative paradigm.

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Map Supplement

Seasonal Land-Cover Regions of the United States

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> Regionalization, an important and classic method of geographical research, requires new refinements and innovative applications for use in analyzing global change. (Mather and Sdasyuk 1991:152)

Research on global change has been hindered by deficiencies in the availability and quality of land-cover data (Mather and Sdasyuk 1991; Townshend 1992). To address this deficiency, the U.S. Geological Survey (USGS) and the University of Nebraska-Lincoln have collaborated in developing a method of land-cover characterization that is suitable for research on global change and on regional patterns of land cover (Loveland et al. 1991; Brown et al. 1993). This methodology is based upon statistical analysis of multidate, meteorological satellite imagery acquired by the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) sensor complemented by ancillary spatial data. The product of this analysis—a multi-level, digital, geographically referenced land-cover database (hereafter referred to as the *database*) covering the coterminous United States—serves as a prototype for a global land-cover database which is currently under development.

The study of global change requires improved regional frameworks (for example, Turner, Moss, and Skole 1993; Mather and Sdasyuk 1991). The land-cover characterization strategy developed in this study is based upon regionalization of the seasonal expression of vegetative development. This approach is well-suited for global-change r search because of the explicit manner in whi critical biophysical conditions are used to d fine and characterize land-cover region Moreover, the regionalization process pr sented here has the advantages of replicabilit computational manageability, flexibility, an global applicability.

The USGS-Nebraska study was undertak in order to generate digital maps for climati hydrologic, and ecologic modeling and oth applications in which land-cover data are r quired (Steyaert et al. 1994). This paper drav upon that digital database in constructing ma of selected land-cover characteristics of t continental United States. These maps are illu trative of the variety of maps that can be pr duced from the digital database. The paper d scribes the methods used to prepare the dat base, presents an experimental map suppl ment portraying seasonal land-cover regions the U.S. based on the analysis of multitempo AVHRR and ancillary spatial data, and provid guidance for prospective users of the digi database.

The maps in this paper represent a few the cartographic products that might be d rived from the database. Many others are po sible, however, because our approach affor users the opportunity for customizing produ to specific needs. Because no single map or s of maps can convey fully the richness of t database, visualization tools such as tho commonly found in geographic informati systems (GIS) as well as new specialized ca

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tographic software provide appropriate means for exploiting the database (for example, Egbert and Slocum 1992).

Global Land-Cover Requirements for Biophysical Modeling

Because of the wide variety of scales, classification schemes, and derived land-cover parameters that are employed by students of global change, current global land-cover databases (UNESCO 1973; Olson and Watts 1982; Matthews 1983) are unable to fill many emerging research needs. Consequently, the selection of a land-cover framework usually depends more on data availability than on the suitability of that framework for the problem at hand. Equally problematic is the wide range and variety of global-change applications which require land-cover data. These include such different applications as atmospheric mesoscale and general circulation modeling, water-resources assessment, and ecological modeling (for more extensive reviews, see Baker 1989; Henderson-Sellers and McGuffie 1987; Sklar and Costanza 1990; and Goodchild et al. 1993). Accordingly, land-cover typologies and their spatial resolutions will vary both within and between applications. Table 1 summarizes the land-cover inputs (classification schemes, attributes, and spatial scale) required by ten selected models.

In the case of atmospheric models, climatologists and meteorologists construct mesoscale and general circulation models (GCMs) to estimate a range of future weather or climate conditions. Mesoscale models operate in a regional context with typical spatial resolutions of 1 to 40 kilometers; GCM's are global in scale and require resolutions on the order of 2 × 4 degrees latitude/longitude or greater. Models at both scales use land-surface parameterization schemes to determine land/atmosphere interactions. For example, the Biosphere Atmosphere Transfer Scheme (BATS) (Dickinson et al. 1986) and the Simple Biosphere Model (SiB) (Sellers et al. 1986; Xue et al. 1991) link data on land cover with measures of fractional land cover, roughness, albedo, and other land characteristics for calculating water and energy-exchange fluxes for grid cells. Note, however, that the land-cover types used in BATS and SiB differ in the number of classes (there are 18 BATS versus 13 SiB classes in the U.S.), the definitions of classes, and the variety of attributes that describe land-cover properties.

Similarly, hydrological models typically require information on land cover, soils, and terrain for the purpose of defining homogeneous hydrologic-response units (HRUs) for their computations. HRUs typically are defined by relatively simple land-cover classes, e.g., bare soil, grasses, bushes/shrubs, and trees, and for multiple grids, e.g., 2.5-, 5-, and 10-km grid cells or variously sized polygons associated with watershed basin characteristics.

Ecosystem models meanwhile use land-cover data for estimating a range of measures of ecosystem functions and dynamics, e.g., primary productivity, biogeochemical cycling, and biogenic emissions. The ecosystem model CENTURY simulates the temporal dynamics of soil organic matter and plant production in grazed grasslands (Parton et al. 1987; Burke et al. 1991) using land-cover (particularly land-use) and monthly climate data as key inputs. The specific land-cover classes used in the CENTURY model vary, however, according to the application. The Regional Hydrological Ecosystem Simulation System (RHESSys) model requires, by contrast, broad land-cover data at the biome scale, i.e., grasses, shrubs, coniferous, and deciduous forests, at 1- to 60-km grid cell sizes. This model uses land-cover attributes for each cover class in combination with satellite-derived estimates of leaf area and daily weather data in order to calculate water, energy, and trace-gas fluxes (Running 1990).

Table 1. Land-Cover Characteristics Input Requirements and Spatial Scale for Selected Modeling Applications and Models.

	Model	Classification Scheme	Spatial Scale	Associated Attributes
General Circulation Models	NASA/GSFC	SiB	4 × 5 degrees	SiB set and NDVI derivatives
	University of Maryland-COLA	Simplified SiB	4.5 × 7.8 degrees 1.8 × 2.8 degrees	SSiB set and NDVI derivatives
	NCAR-CCM	BATS	2 × 4 degrees	BATS set and NDVI derivatives
Mesoscale Meteorological Models	CSU-RAMS	LEAF	Nested Grids of 1, 10, 40 km	LEAF Set and NDVI derivatives
	PSU-NCAR MM4	BATS	Nested Grids of 4, 12, 36 km	BATS Set and NDVI derivatives
Hydrologic Models	Watershed Precipitation/Runoff	Basic Classes	2.5, 5, 10 km	model specific
	Agricultural Chemical Runoff	Anderson Level II	country level or 1 km	model specific
Ecosystem Models	RHESSys	Basic Biomes	1–50 km	RHESSys Set and NDVI derivatives
	CENTURY	Anderson Level II	1–50 km	NDVI derivatives
	Biogenic Emissions	Key species (oak, hickory, etc.)	20 km	NDVI derivatives

Table of Abbreviations

BATS	Biosphere-Atmosphere-Transfer-Scheme
COLA	Center for Ocean-Land-Atmosphere
CSU-RAMS	Colorado State University-Regional Atmospheric Modeling System
GSFC	Goddard Space Flight Center
LEAF	Land-Ecosystem-Atmosphere-Feedback
NCAR-CCM	National Center for Atmospheric Research, Climate Community Model
NDVI	Normalized Difference Vegetation Index
PSU/NCAR-MM4	Penn State University/National Center for Atmospheric Research-Mesoscale Meteorology
RHESSys	Regional Hydrological Ecosystem Simulation System
SiB	Simple Biosphere model
SSiB	Simplified Simple Biosphere model

Optimal Global Land-Cover Data for Global-Change Research

Existing land-cover maps of the continents and the globe are uniformly small in scale, coarse in spatial resolution, variable in quality and reliability, and ill-suited for alternative modeling applications (Townshend 1992; Henderson-Sellers and Pitman 1992; Townshend et al. 1991). Accordingly, the design of an optimal land-cover data set for global-change research should overcome these deficiencies. It should: 1) derive from a single set of relatively high-resolution source data acquired within a narrow window of time (e.g., 1 or 2 years); 2) employ a flexible land-cover classification that permits users to tailor their products for specific applications; 3) rely upon systematic analytical procedures; 4) capture important seasonal and interannual trends; 5) facilitate biophysical interpretation; and 6) ensure replicability for the purpose of long-term monitoring (Townshend 1992).

Conventional land-cover maps do not achieve these objectives since their developers have designed them to serve the singular purposes of specific user-groups. Digital spatial databases, by contrast, enable all users to extract the data and create customized maps and other products that meet specialized user requirements (Goodchild 1988). The virtues of such a flexible database are increasingly obvious since they permit multiple applications as well as the opportunity to interactively "explore the database underlying a map" (Egbert and Slocum 1992).

Land-Cover Regionalization

Regionalization, long a hallmark of geographic research (Grigg 1965; 1967; Spence and Taylor 1970; Gardiner and Gregory 1977; Haggett et al. 1977; Hart 1982; Turner, Moss, and Skole 1993), is garnering increasing attention among students of global change (Mather and Sdasyuk 1991; Peplies and Honea 1992).

The latter have realized that regions can serve as units of analysis that capture important aspects of landscape variability over large areas. In addition, regions offer an efficient and flexible spatial framework for summarizing the often complex ecosystem parameters that are required in environmental modeling (Omernik and Gallant 1990).

The rich and extensive literature on regionalization is, of course, well-known to geographers (for example, Grigg 1967; Haggett et al. 1977; Hart 1982). For purposes of this paper, we employ a method of land-cover regionalization which defines uniform regions based upon seasonal characteristics of land cover augmented by other descriptive attributes. Regionalization, in this regard, represents a special form of classification (Grigg 1967). Classifications of landscape regions may be based on one variable (monothetic) or many (polythetic) (Spence and Taylor 1970; Gardiner and Gregory 1977). Examples of monothetic or univariate regionalization include Kuchler's map of the potential vegetation of the United States and Anderson's depiction of land-use and land-cover regions for that same nation (Kuchler 1964; U.S. Geological Survey 1970). Polythetic or multivariate regionalization (Spence and Taylor 1970) is illustrated by the maps of ecoregions (produced by Omernik 1987; and Bailey 1980; 1983) which are defined as multivariate associations of climate, geology, terrain, soils, and vegetation.

Our classification of land-cover characteristics for the United States is most closely related to the polythetic regionalization model. This decision signals a departure from the norm of land-cover regionalizations derived from remote sensing which employ a monothetic approach. In these cases, image analysts assign each pixel to one, and only one, category in a land-cover classification system (such as, for example, Anderson et al. 1976; or Jennings 1993). While the monothetic approach may produce land-cover maps that are well-suited for certain types of land-management activities (e.g., wildlife-habitat evaluation or soil-erosion hazard assessment), the method lacks the flexibility that is required for many environmental models (Omernik and Gallant 1990). The fact that monothetic mapping is often designed for a specific need for land-cover data means that this procedure is usually ill-suited for other applications (Peplies and Honea 1992). For optimal flexibility of usage, a land-cover database should accommodate a broad range of temporal, spatial, and categorical aggregations that are suited to variable applications requirements (Peer 1990; Reed et al. 1994b). Achieving such flexibility is the main purpose for which the U.S. land-cover database has been designed.

Sources of Land-Cover Data: Satellite Remote Sensing

Earth-observing satellites (e.g., Landsat, SPOT) have been collecting data for more than 20 years. These data are routinely used for land-cover assessment, although several practical issues have limited their usefulness for land-cover mapping over subcontinental or larger areas (Goward 1990). The large volume of data (number of scenes and number of pixels) required to cover even a single continent and the complexity of data acquisition and analysis have made such analyses prohibitively expensive (see Woodwell et al. 1984). Moreover, the revisit period (e.g., 16 days for Landsat) of the current earth-observing satellites is such that, in most instances, the generation of a cloud-free high-quality set of images entails assembling scenes acquired over several years and many seasons.

Because of such difficulties in using earth-observing satellites for large-area land-cover assessments, attention in recent years has shifted to the potential application of meteorological satellite data for such ventures. Most efforts have focused on the Advanced Very High Resolution Radiometer (AVHRR), a sensor carried on the National Oceanic and Atmospheric Administration's (NOAA) series of polar-orbiting meteorological satellites. The AVHRR provides low-cost daily global coverage at 1.1 by 1.1 kilometer spatial resolution (note that we resampled the 1.1-km^2 AVHRR data to a nominal 1-km resolution for this study; hence, subsequent references are to the 1-km data). The high frequency of observation affords many opportunities for acquisition of cloud-free data over relatively short periods of time (e.g., a growing season) and facilitates the compilation of information on seasonal changes in land-surface characteristics. Moreover, the 1-km spatial resolution produces a manageable volume of data even for the global scale (Townshend 1992).

Although designed mainly for atmospheric rather than earth observation, the AVHRR sensor is also useful for land-cover assessment. In most instances, data from AVHRR channels 1 (reflected red light—0.58 to 0.68 micrometers) and 2 (reflected near infrared—0.725 to 1.10 micrometers) are used to compute an index of vegetation "greenness" (the normalized difference vegetation index or NDVI) for each 1-km pixel (Eidenshink 1992). This index of "greenness" is broadly correlated in turn with several biophysical parameters such as levels of photosynthetic activity, primary production, leaf area, and CO_2 flux (see Box et al. 1989; Goward and Huemmirch 1992; Ludeke et al. 1991; Spanner et al. 1990; and Tucker et al. 1983).

Cloud-free greenness maps of the earth's surface are assembled from multidate composite images. The USGS EROS Data Center, for example, produces a 14-day composite greenness image for the coterminous U.S. (available on CD-ROM; Eidenshink 1992). The EROS composite images are constructed by assigning each pixel the highest NDVI recorded in that pixel during the 14-day period. This process tends to eliminate clouds except in areas where there are no cloud-free pixels during the 14-day period. A time series of these composite "greenness" images depicts phenological events, most notably the annual progression from Spring greenup ("green wave") when the northern hemisphere's deciduous trees develop leaves and crops emerge and develop to the ensuing Fall's retrogression ("brown wave") when trees drop their leaves and crops reach senescence and are harvested (Goward et al. 1985; Goward 1989). With data such as these we are able to define regions having distinctive seasonal characteristics.

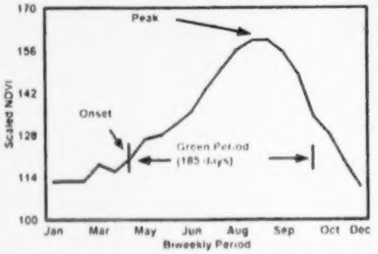

Figure 1. Sample temporal profile for the central Corn Belt showing the relationships between NDVI and the timing of the onset and peak of greenness and the duration of the green period in 1990.

The graph in Figure 1 provides an example of a greenness (NDVI) profile for Iowa. The graph describes the characteristic increase in greenness ("onset") starting in May as the row crops (e.g., corn and soybeans) emerge and develop, the peaking of greenness in early August as crops reach their maximum development, and the decrease of greenness in early Fall associated with senescence and harvest. Iowa's profile of greenness advance, peak, and retreat is quite different, however, from other areas with different cover types. The U.S. database project takes advantage of this variability in sequencing which enables land cover in a given region to be characterized by the annual multitemporal trajectory of greenness associated with that region.

The utilization of AVHRR data for large-area, land-cover assessment extends back nearly 15 years (Townshend et al. 1991). Most of this research uses AVHRR data resampled to 4-km^2 or 16-km^2 pixels. For example, AVHRR data at a resolution of 4-km^2 has been used for defining major biomes and observing phenological change over the African continent for a 19-month period in 1982 and 1983 (Tucker, Townshend, and Goff 1985), and for classifying land cover in South America (Townshend, Justice, and Kalb 1987). Moreover, seasonal NDVI patterns have been used to test associations with major land-cover regions of North America and to document major phenological events (Goward, Tucker, and Dye 1985). World biomes have been mapped using a supervised binary decision tree classification of multidate AVHRR data (Lloyd 1991), and global phytoclimatological conditions have been examined using biweekly AVHRR data (Gallo and Brown 1990).

The use of finer-resolution AVHRR data for land-cover assessment is less common because the data generally are not available over large areas of the globe (Ehrlich, Estes, and Singh 1994). Studies that have employed 1-km AVHRR data have usually focused on small ar-

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eas (see Tucker, Gatlin and Schneider 1984; Gervin et al. 1985). Recently, however, several studies have used 1-km AVHRR data for large area land-cover studies. Using 1-km AVHRR data, Zhu and Evans (1994) mapped forest types and forest density for the coterminous United States, and Stone et al. (1994) constructed a general land-cover map of South America (largely from 1-km AVHRR data). One-kilometer AVHRR data also have been used for mapping general land-cover patterns of Canada as part of a national atlas project (Palko 1990). Promising as well is a collaborative effort aimed at providing data needed for a range of global-change research initiatives. In this case, a consortium of the USGS, National Aeronautics and Space Administration (NASA), NOAA, the European Space Agency, and the International Geosphere Biosphere Programme is developing a global time series of 1-km AVHRR data for the period April 1992 to September 1994.

Producing the U.S. Land-Cover Database

The production of the U.S. 1-km land-cover database began with assemblage of a national coregistered 1-km dataset consisting of a set of eight monthly maximum NDVI composite images covering the period March–October 1990 along with data on elevation, climate, ecoregions, and related attributes (Loveland et al. 1991; Brown et al. 1993). The eight NDVI images were statistically clustered using the Isoclass clustering algorithm, a per-pixel algorithm which has no contiguity constraints. The algorithm yielded 70 spectral-temporal ("seasonally-distinct") classes (regions). These regions were then collated with Landsat imagery, existing vegetation map observations, and other reference materials in order to develop a preliminary description of land cover in each of the 70 regions. These land-cover descriptions were then refined using a postclassification sorting procedure (Brown et al. 1993). Classes with similar seasonal NDVI profiles, but different vegetative components, were subdivided into internally homogeneous land-cover regions. This resulted in a database containing 159 seasonal land-cover regions and their corresponding descriptions.

The 159 land-cover regions were then cross-tabulated with elevation, climate, ecoregions, land use, land cover, and ancillary data sets. This cross tabulation enables database users to determine the topographic and climatic characteristics of a given land-cover region. Tables linking the AVHRR-derived database and other commonly used land-cover classification systems (e.g., Anderson's USGS scheme, BATS, and SiB) were created to facilitate translations between the systems. Finally, parameters such as the timing of vegetative onset and peak greenness and the duration of the green period were derived from AVHRR data for January–December 1990. The entire U.S. database—including source data, classification, derived and ancillary data, tabular data, and documentation—is available on CD-ROM (USGS EROS Data Center, Sioux Falls, SD 57198) (Table 2).[1]

Preparing the Map Supplement

We then turned to the cartographic representation of these data. An experimental map portraying the land-cover regions and selected seasonal characteristics was produced. This 1:7,500,000-scale map depicted the 159 seasonal land-cover regions grouped into major cover types. The legend listed typical vegetation or land-cover types found in each region. In some cases, two or more classes were indicated as having the same land-cover types. In these cases, the several regions share common land-cover attributes, but differ in the seasonal characteristics of vegetative development or in the relative levels of vegetative productivity.

The presentation of the 159 seasonal land-cover regions at this small a scale constituted a major challenge. Because of the fine spatial resolution of the database and because some of the regions are very small, techniques such as pattern overlays or region labeling (as used on Küchler's map of potential natural vegetation) were not feasible. We developed instead a technique that designated a distinct hue for each group of cover types. The selection of hues was based on standard cartographic conventions for color representation of vegetation types, i.e., green for forests and yellow for grasslands. Within each cover-type group, darker hues represent increasing relative levels of annual primary production (estimated from annual total NDVI). For example, we divided "savanna" in the grasslands group into four regions (classes 86–89) based on seasonal greenness patterns; these appear as a graduated series of yellow hues. The light yellow hue of Class 86 indicates relatively lower annual primary production than the darker yellow hue of Class 89.

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Table 2. U.S. Land-Cover Characteristics Database.

Land-cover Classifications

Preliminary Classification (70 Classes)
Final Classification (159 Classes)

Source Raster Files

1990 March–October 28-day NDVI composites (Eidenshink 1992)
1990 maximum NDVI
USDA Major Land Resource Areas (USDA 1981)
EPA ecoregions (Omernik 1987)
Digital elevation
Water bodies (lakes, reservoirs, and large rivers)
USGS Land Use and Land Cover (USGS 1986)
Frost-free period (NOAA 1979)
Political boundaries

Derived Raster Files

USGS Land Use and Land Cover
Simple Biosphere Model
Biosphere-Atmosphere Transfer Scheme
Onset of greenness
Peak of greenness
Duration of greenness

Descriptive and Statistical Attributes

Major vegetation and land-cover types
1990 NDVI statistics
1990 AVHRR channels 1–5 statistics
Elevation statistics
USGS Land Use and Land Cover statistics
USDA Major Land Resource Areas statistics
EPA ecoregions statistics
Seasonal characteristics
Frost-free period statistics
Climate summary statistics

In addition, we had to accommodate the large number of regions, some quite small in area, and the difficulty of differentiating among the 159 uniquely colored classes. Toward that end, color selection has taken into account regional contiguity in order to minimize the assignment of similar colors to adjacent regions. For example, although the shades of green used to symbolize southeast mixed forest and western woodlands are similar, these classes of land-cover are geographically separated and hence more easily identifiable as distinct classes. Conversely, small grains and row crops often occur in adjacent locations, and in order to maintain visual separation, these were assigned colors of orange and brown, respectively.

In addition to the 159-class land-cover map, the map supplement includes several other maps derived from the database. The USGS level II land-cover map on the reverse side of the Supplement portrays the 159 classes in the database aggregated into an approximation of the Anderson land-use and land-cover classification system—one of the most widely used systems in the U.S. (Anderson et al. 1976). The 26 land-cover classes derived reflect regional vegetation types and mosaics of land cover at 1-km resolution. Translation tables for converting between our 159 seasonally based classes and Anderson's classification are part of the database. Our aggregation required some modification of the original Anderson classes because of differences in class characteristics and AVHRR data resolution. For example, instead of using the single level II deciduous forest category, we derived three deciduous forest classes (northern, southern, and western) which differ with respect to the dominant tree species found in each region. Mixed classes such as grassland/cropland and woodland/cropland were classified as complex regions with interspersed land-use/land-cover types.

The Map Supplement also contains a series of smaller-scale maps depicting 1990 seasonal characteristics of the 159 land-cover classes. One series of maps portrays the months in which the onset of greenness and peak greenness occurred and the other depicts the duration of the green period (an estimate of the length of growing season). Note that the Map Supplement presents monthly estimates of onset and peak seasonal characteristics (Figure 1), whereas our calculations of onset and peak are based on the nearest 1990 14-day period.

Onset of greenness is defined as the period in which significant development of standing green biomass was observed through the NDVI. Using a temporal NDVI profile graph, onset is typically defined as that point of steep upward inflection in the NDVI curve following the dormant season. Interpretation of this point is somewhat subjective, however, and the search for an objective quantitative means for detecting seasonal events from NDVI is underway (Reed et al. 1994a).

The maps portraying peak-greenness months are based upon the biweekly period which reported the highest level of greenness (NDVI) in 1990, i.e., the time period of maximum NDVI mean value for each of the 159 classes. Lastly, the map of the Length of Green Period shows the duration of greenness—defined as the number of days between onset and end of greenness (Figure 1). The end of the green period we defined as the biweekly period in which the NDVI dropped to a seasonal low corresponding to the NDVI level at the onset of greenness. The interval between the onset and the end of greenness thus equals the duration of the green period (expressed as number of days).

Interpreting the U.S. Land-Cover Map

The 159-region maps are based upon a remotely-sensed dataset collected over a single year. These maps have several advantages: 1) their resolution (1 km) is substantially finer than most comparable products; 2) the large number of regional classes exceeds those of similar maps (for example, U.S. Geological Survey 1970; Kuchler 1964; Omernik 1987; Bailey 1980); and 3) the 159 regional classes incorporate seasonality and productivity as well as land cover. Whereas comparable maps present a single set of regions labeled "wheat," we discern several wheat regions with varying crop calendars (i.e., planting/harvesting dates) that correspond to higher latitude and/or elevation or climatic gradients. Moreover, because the land-cover data are registered to other databases (e.g., elevation, climate, ecoregions), users can explore relationships between the several datasets and construct products designed for their specialized needs.

Because the original AVHRR data have a resolution of approximately 1-km, mixtures of land-cover are commonly integrated within the AVHRR pixel. Even in areas largely devoted to crops, a 1-km pixel will usually contain tracts of woodland, grass, and other cover types that exhibit phenologies different from crops. This is particularly evident in areas such as the Middle Atlantic states, where land cover is both diverse and highly fragmented into small parcels.

At first glance, the spatial complexity of the 159-class map may seem disconcerting, even noisy. While cartographers are still debating the merits, role, and procedures for data classification and presentation—generality versus detail—(Dent 1993; Egbert and Slocum 1992; Tobler 1973), our map aims to convey the overall pattern of land cover in a single year and to provide a realistic depiction of the spatial patterns of land cover. The 1-km spatial resolution enables us to portray the fragmentation and patchiness of land cover which are not usually apparent in more generalized maps. In addition, by revealing the fuzzy nature of ecotones separating major landscape regions, the map underlines the role of ecotones as transition zones (Clarke et al. 1991).

The Map Supplement portrays many familiar patterns among the seasonal land-cover regions. Note, for example, the distinctive and relatively homogeneous land cover of the Corn Belt, the Ozark Uplands, the Palouse of Washington and the Flint Hills of Kansas. The map also captures the differences in the spatial structure of land cover across the nation. The highly fragmented depiction of the interior western landscapes of the basin and range province, for example, reflect the often dramatic variation in relief, elevation, and microclimate over relatively short distances in this region. The expression of underlying physical geography is evident elsewhere as well—on the eastern fall zone, the ridges and valleys of the southern Appalachian Mountains, along the Willamette valley of Oregon, amidst the Nebraska Sand Hills, and within the Black Hills of South Dakota.

Patterns on the derivative maps are, perhaps, less familiar because they have been infrequently (if ever) mapped at the spatial and temporal resolution of our database. Comparisons between the seasonal land-cover regions map and the derivative maps of onset, duration, and peak of greenness are informative and, at times, expose surprising relationships. For example, the late date of the onset of greenness in the croplands of the Mississippi floodplain (downstream from Cairo, Illinois) does not correspond with the seasonal characteristics of the surrounding region. Given a moderate climate, one might expect that crops there would be planted and mature to their peak greenness quite early by comparison to crops at more northerly latitudes. The maps show that this was not the case in 1990. The maps thus lead us to explore this apparent anomaly. Anecdotal evidence suggests that high water tables and abundant precipitation in the spring may have resulted in saturated fields which delayed planting in this region; the matter clearly deserves more thorough research. Doubtless examination of the maps will reveal other anomalous areal relationships between land cover and regional seasonality. Some of these may reflect the specific meteorological conditions that existed in 1990, while others may suggest more durable anomalies that merit investigation.

Note that the 159-class map portrays seasonally distinct land cover and *not* land use (Campbell 1983). As a consequence, urbanized areas are represented by their constituent land-cover types (e.g., grassland, woodland, barren). Moreover, because class labeling has been optimized at the national level, urban mosaics of roads, buildings, and parks may appear as "desert shrubland" since their spectral and temporal characteristics often resemble that cover type. Persons interested in urban areas should be aware of the causes of this apparent mislabeling and may wish to assign more appropriate labels to areas of interest. Ancillary data sources can, of course, be used to identify urban areas as demonstrated in our USGS Level II Land-Cover map. In this case, urban areas were derived from the Digital Chart of the World and overlaid into the AVHRR-derived general land-cover map in order to provide map readers with a portrayal of the spatial extent of urban areas as well as an example of complementary use of data from different sources (Danko 1992).

Understanding Seasonal Land-Cover Characterization

To facilitate interpretation of the seasonality inherent in the land-cover database, we present a brief analysis of some representative land-cover classes. The temporal greenness profiles in Figures 2-5 depict the average NDVI for each of eight classes over the twenty-two 14-day intervals in 1990. Similar profiles for all other classes can be extracted from the database.

Figure 2 displays 1990 NDVI profiles for two agricultural regions: 1) Class 9, found in the southern Great Plains and eastern Washington, is cropland planted primarily in winter wheat; and 2) Class 17, found in the midwest corn belt, is cropland planted primarily in feed grains, especially corn and soybeans. Both NDVI profiles exhibit steep increases and decreases in greenness corresponding to crop development, senescence, and harvest. In the corn-soybeans region, greenness begins its increase in May as crops emerge, peaks in mid-August as these crops reach their maximum biomass and photosynthetic activity, and decreases in September as senescence and harvest set in. In the winter wheat region, by contrast, greenness increases in March as fall-sown winter wheat emerges in early spring, peaks in late-April, and decreases in early summer as crops are harvested.

Figure 3 presents the profiles for two classes dominated by deciduous forest: 1) Class 92 in the northern Great Lakes States is dominated by maple, birch, and beech forests; and 2) Class 94 in the central Appalachian Mountains and northern Ozarks is dominated by oak and hickory forests. In the former, the onset of greenness occurs in May with the emergence

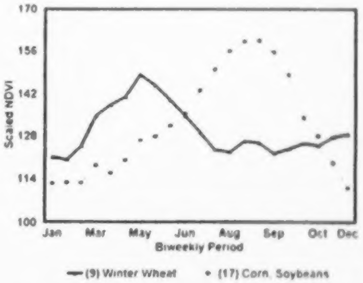

Figure 2. 1990 NDVI characteristics for selected seasonal land-cover regions: winter wheat and corn-soybeans.

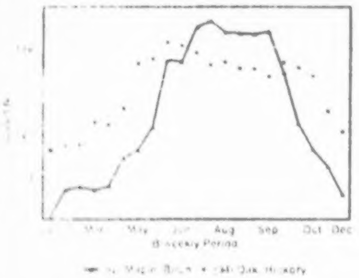

Figure 3. 1990 NDVI characteristics for selected seasonal land-cover regions: maple-birch and oak-hickory.

of leaves, is followed by a steep increase in the NDVI from spring to the summer period of maximum photosynthesis, and then by a rapid decline in NDVI levels in September as leaves change color and defoliate. In the latter, the shape of the greenness profile is similar to that of the northern hardwoods region, but the onset of greenness (April) is earlier because of the more southerly latitude. In addition, the longer growing season occasions later defoliation (late-October).

Figure 4 depicts two coniferous forest types: 1) Class 98 is dominated by southern pines, including loblolly, longleaf, shortleaf, and slash pines; and 2) Class 105 is comprised principally of lodgepole and ponderosa pine in Colorado. In the case of the southern pines, the evergreen forest cover results in a relatively high NDVI level throughout the year. The decrease in the NDVI in January and February likely is attributable to low sun angles, the corresponding shadows of mid-winter, and reduction of the forest understory. As for the Colorado pine, the greenness profile describes a distinct seasonality that more nearly resembles the NDVI profiles for deciduous cover types. In this case, the rapid increase in NDVI values in late-April and May probably results from higher sun angles, the gradual melting of the winter snow cover, and the subsequent development of the forest understory.

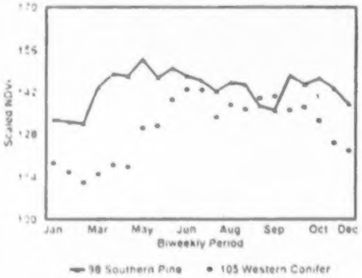

Figure 4. 1990 NDVI characteristics for selected seasonal land-cover regions: southern pine and western conifer.

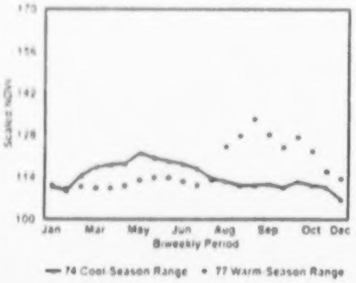

Figure 5. 1990 NDVI characteristics for selected seasonal land-cover regions: cool-season rangeland and warm-season rangeland.

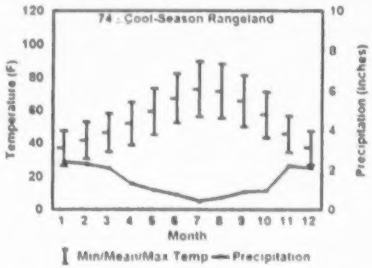

Figure 6. Monthly temperature and precipitation (30-year averages) in areas within rangeland class 74. This graph illustrates the influence of climate variables on NDVI signals (see Figure 5 to compare the NDVI profile for class 74 cool-season grasses).

Figure 5 displays NDVI profiles for two rangeland regions: 1) Class 74 is composed primarily of shrubs (big sage and rabbitbrush) and cool-season grasses (wheat grass and fescue) distributed throughout Washington, Oregon, and Idaho; and 2) Class 77 is a mixture of shrubs (creosote and sand sage) and warm-season grasses (grama) found principally in the southwestern U.S. Note that overall NDVI levels are lower here than in forested and agricultural regions, a reflection of the lower amounts of standing primary production in these semiarid environments. The profiles for these classes also illustrate the response of vegetation to rainfall patterns in semiarid climates. The profile for Class 74 (in the Northwest) exhibits a spring green period that is related to late winter and early spring rains, while the profile for class 77 (in the Southwest) shows a later increase and peak greenness triggered by summer rainfall (Figures 6 and 7).

Our maps of the land-cover characteristics in the U.S. presented here are for 1990, hence they reflect climatic conditions in that year. As Changnon and Kunkel (1992) have pointed out, 1990 was an anomalous weather year in the midwest where it was both the warmest and wettest year on record. They also note that weather conditions across the country in 1990 were unusual. The year was the seventh warmest and the fourteenth wettest on record since 1895. Above normal precipitation between January and June in the midwest delayed the growing season (planting) by several weeks. Weather conditions also led farmers to shift more than 18 million acres from corn to soybeans. In addition, the cool and wet spring favored pest development, and higher-than-normal winds in spring and summer minimized opportunities to spray crops. The effects of these combined phenomena are reflected in the database and in the AVHRR-derived maps.

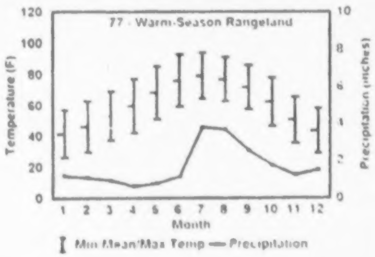

Figure 7. Monthly temperature and precipitation (30-year averages) in areas within rangeland class 77. This graph illustrates the influence of climate variables on NDVI signals (see Figure 5 to compare the NDVI profile for class 77 warm-season grasses).

Because AVHRR data are continuously collected and archived, it is possible to examine seasonal land-cover-climate relationships for years since 1990. The USGS EROS Data Center now provides AVHRR biweekly greenness data as a standard CD-ROM product (Eidenshink and Hutchinson 1993). Explorations of the seasonal manifestations of greenness-weather relationships for the U.S. land-cover regions over the period 1990–1993 are currently underway (Reed et al. 1994a).

Evaluation of the Database

Methods for determining the accuracy of products generated via remote sensing are well-developed for conventional image-analysis projects covering relatively small areas (Congalton 1991), but techniques for validation of continental-scale or global-scale maps and databases are still at an earlier stage of development (Goodchild 1988). The usual procedure involves assessing the results of an analysis of remotely-sensed data against "ground truth." In the case of the U.S. database, however, almost 8000 1-km contemporaneous samples on the ground would be required to conduct a conventional accuracy assessment (Congalton 1991). Moreover, it is far from clear what standard of reference should be used to compare the U.S. land-cover regions (Merchant et al. 1994). The classification methods

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and the data used, the number and types of categories mapped, and the spatial resolution of the U.S. database project differ considerably from those employed in conventional land-cover mapping efforts. Consequently, no rigorous accuracy assessment of the U.S. database has as yet been completed.

Nevertheless, a number of preliminary studies indicate that the database offers a reasonable depiction of U.S land cover. D. P. Turner et al. (1993), evaluating an early version of the database, compared forested areas in the 1990 U.S. database with the 1987 forest inventory data of the U.S. Forest Service (USFS). Their state-, regional-, and national-level areal assessments in states having large contiguous tracts of forest cover report close agreement between the USFS data and the AVHRR-derived estimates of forest. At the national level, the USFS and AVHRR estimates of forested land differed by only about 4 percent. Similar estimates for county forest cover in the northeastern portion of the U.S. indicate that the two sources compare very favorably (Lathrop and Bogner 1994), subject however to the caveat that validation is difficult because of the differences between the classification schemes used by the USFS and the AVHRR database.

Similar agreement has been found by Merchant et al. (1994) who compared portions of the U.S. database to several independently developed state land-cover maps (Tables 3 and 4). When AVHRR-derived data for Nebraska were compared to USGS land-use and land-cover (USGS/LULC) maps derived from interpretation of high-altitude aerial photography and to the U.S. Department of Agriculture (USDA) areal land-use data, they found the cropland/grassland estimates within 3 percent (USGS/LULC) and 8.3 percent (USDA), cropland only estimates within 1 percent (USDA only), rangeland only estimates within 8 percent (USGS/LULC) and 10 percent (USDA), and forest estimates within 0.7 percent (USGS/LULC) and 1.0 percent (USDA). The AVHRR-derived land-cover data and USDA land-use data were also compared to a SPOT land-cover classification for South Carolina (Table 4) and, in this case, agreement was within 2 percent (SPOT) and 0.4 percent (USDA) for agriculture and grassland, and within 2 percent (SPOT) and 0.6 percent (USDA) for forests. Differences between the estimates are related to the coarse resolution of the AVHRR, time differences between the datasets, and so on. Forest cover in Nebraska, for instance, is probably underestimated by the AVHRR because this type of land cover tends to occur in small parcels relative to the 1-km sensor resolution.

Table 3. Land-Cover Estimates for Nebraska, Based on Data for the AVHRR Land Cover, USDA Land Use, and USGS Land-Use/Land Cover (LU/LC).

	AVHRR (percent)	USGS/LULC (percent)	USDA (percent)
Cropland or grassland	99.3	96.3	91.0
Cropland	40.0	Not available	41.0
Rangeland	32.0	40.0	42.0
Forest	0.5	1.2	1.5

At the national level, Merchant et al. (1994) compared the AVHRR land-cover database to USDA/National Agricultural Statistical Service (NASS) county-level data on cropped area. That comparison indicated that the estimates of absolute cropped area in the two datasets were significantly and positively correlated ($r=.825$, $r^2=.680$). A similar association was observed for the proportion of each county in cropland. The authors also concluded that preliminary efforts to validate the AVHRR-derived U.S. land-cover characteristics database, though generally positive, have not been conclusive because: 1) they have been based on areal rather than site-specific comparisons; and 2) the accuracies of the "benchmark" data are not well documented.

Table 4. Land-Cover Estimates for South Carolina, Based on Data for the AVHRR Land Cover, USDA Land Use, and SPOT Satellite Image Classification.

	AVHRR (percent)	SPOT (percent)	USDA (percent)
Agriculture or grassland	19	21	18.6
Forest	64	66	63.4

The need for improved methods for the quantitative validation of large-area, coarse-resolution, land-cover databases is obvious. Until such time as these methods are available, we believe that validation procedures must rely to a great extent on subjective evaluation of the data and on accumulation of evidence supporting or refuting the validity of a specific product (Merchant et al. 1994). The cumulative evidence currently available suggests that the AVHRR-derived land-cover characteristics database is a valid representation of land cover in the United States. In addition to the comparative efforts summarized above, this evidence includes extensive preliminary confirmation of database utility by modelers and other database users (Steyeart et al. 1994) and affirmation of the internal logical consistency in the database (Merchant et al. 1994). And more evidence is on the way in the form of a more objective assessment of the accuracy of the U.S. land-cover database by the USDA/Forest Service and EROS Data Center. Initiated in 1993, this project surveyed approximately 3500 field sites throughout the coterminous U.S.; results of this study are currently being analyzed.

Conclusions

The U.S. land-cover project has demonstrated that multidate-coarse-resolution meteorological satellite data can provide new information about the regional expression of land cover and its seasonal characteristics. This information is useful for many global-change research initiatives and for a broad array of other environmental applications. Seasonal land-cover data derived from analysis of AVHRR imagery readily complement land-cover data obtained through more traditional means (e.g., Landsat, SPOT). The maps presented here illustrate some of the products that may be generated from the land-cover characteristics database, and they point to the flexibility of a database which can be tailored to meet specific requirements.

This paper in particular presents a new classification of U.S. land cover based on AVHRR data. One hundred fifty-nine seasonal land-cover regions are described and mapped according to their vegetative composition, phenology (onset, peak, and length of green period), relative productivity, and other landscape parameters. These seasonal land-cover regions and their unique sets of landscape conditions lend themselves to many types of large-area analyses, not least as a spatial framework for measurement, interpolation, and extrapolation of land parameters.

The strength of the land-cover database described here resides in its unification of land-cover data with a suite of landscape descriptors; the regional classes thus are not simply descriptive labels. Moreover, users are provided with data that are consistent in quality; useful for a variety of scientific applications; and descriptive of the temporal dynamics of landscapes. The database overcomes the problem of customized applications which use similar, but not identical, categorizations that are specific to organization, discipline, or application. Our land-cover characteristics database has the advantage of adaptability to a range of problems.

This research has suggested the possibility of constructing a global land-cover characteristics database using 1-km meteorological satellite imagery and ancillary data. Such an endeavor is now underway, and completion is anticipated by late 1997. Coordinated through the International Geosphere-Biosphere Programme (IGBP 1994), the global database is being developed on a continent-by-continent basis using methods developed in the U.S. project. North and South America will be completed by late 1995. Concurrent research is being directed toward improving our analytic techniques, efficiency, and the quality of the results. More specifically, we are investigating means for validating large-area land-cover databases, the interannual variability of land-cover and associated issues, methods for objectively defining seasonal parameters, and visualization techniques for data analysis.

Note

1. The land-cover characteristics database for the coterminous U.S. (including all data outlined in Table 2) is available on CD-ROM. These data can be imported into most raster-based image processing and GIS software packages. U.S. AVHRR NDVI composite data from 1989 to the present and a companion containing additional spatial datasets for the coterminous U.S. are also available on two CD-ROMs. To obtain additional information, contact Customer Services, USGS/EROS Data Center, Sioux Falls, SD 57198; Teleph[illegible] 605-594-6151.

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to address requirements of the global-change research community and others interested in regional patterns of land cover. An experimental 1-kilometer-resolution database of land-cover characteristics for the coterminous U.S. has been prepared to test and evaluate the approach. Using multidate Advanced Very High Resolution Radiometer (AVHRR) satellite data complemented by elevation, climate, ecoregions, and other digital spatial datasets, the authors define 159 seasonal land-cover regions. The regionalization is based on a taxonomy of areas with respect to data on land cover, seasonality or phenology, and relative levels of primary production. The resulting database consists of descriptions of the vegetation, land cover, and seasonal, spectral, and site characteristics for each region. These data are used in the construction of an illustrative 1:7,500,000-scale map of the seasonal land-cover regions as well as of smaller-scale maps portraying general land cover and seasonality. The seasonal land-cover characteristics database can also be tailored to provide a broad range of other landscape parameters useful in national and global-scale environmental modeling and assessment. **Key Words:** global change, land cover, phenology, remote sensing.

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Population, Development, and Tropical Deforestation: A Cross-national Study[1]

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Abstract In the past 15 years, the international development community has focused on rapid tropical deforestation with considerable concern. This paper makes a preliminary effort to specify the causes of tropical deforestation. In the early 1980s a special United Nations' study generated reliable estimates of rain-forest destruction for 36 developing countries. A cross-sectional analysis which links variations in deforestation with variations in population growth and the availability of capital indicates the socioeconomic processes which sustain tropical deforestation. Two measures of population growth predict deforestation, and among countries with large rain forests, the availability of capital also predicts deforestation. Measures of peripheral country dependency on core nations fail to explain variations in deforestation. The implications of these findings for policies designed to slow rates of deforestation are briefly explored.

Introduction

In recent years, numerous observers have voiced concern over the destruction of tropical rain forests in Africa, Asia, and Latin America (Myers 1984; Shane 1986). The reasons for concern fall into two general categories: First, rain forests exhibit the most diversity among species of all the major biological communities, so their destruction would result in massive species extinctions, with an attendant impoverishment of the world's genetic resources. A second concern voiced by climatologists is that tropical deforestation contributes to the climatic changes commonly referred to as the greenhouse effect. Computer simulations of the climatic changes project a series of associated changes (such as rising sea levels and more frequent droughts in the North American grain belt) which would require difficult adjustments. Because tropical deforestation has human rather than natural causes, the search for reasons why it has accelerated in the late twentieth century and why it varies in extent from place to place leads directly to phenomena familiar to rural sociologists. Changes in rural populations, their social structures, and their ties to the larger world system offer a plausible starting point in the search for causes of variable rates of deforestation.

As with other attempts to interpret change in Third-World settings

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[1] Helmut Anheier, Mike Gildesgame, Tim Jessup, George Morren, Andrew P. Vayda and four anonymous reviewers for *Rural Sociology* made valuable comments on this paper. An earlier version of the paper was presented at the Rural Sociological Society meetings in Madison, Wisconsin in 1987.

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(London 1987), the initial attempts to explain tropical deforestation have taken either a human-ecological or a political-economic form. The ecological perspective identifies growing populations of peasant or subsistence cultivators as the chief cause of tropical deforestation (Myers 1984; World Resources Institute 1985). In this argument, small farmers, compelled by the Malthusian necessity of a growing population, leave their lands fallow less and less. The shortened fallow periods prevent forest regrowth, and a region gradually becomes deforested. A Peruvian report (Dourojeanni 1979, cited in Myers 1984:150) describes a variant of this process in graphic terms.

> The population overflowing from the Andes down to the Amazon plains do not settle there. They advance like a slow burning fire, concentrating along a narrow margin between the land they are destroying and are about to leave behind, and the forests lying ahead of them.

In other words, deforestation results from a growing population's *sustenance-related endeavors* (Poston et al. 1984:116).

The second perspective on the causes of tropical deforestation is the political economic one. This perspective emphasizes the role of public and private capital in raising rates of deforestation (Hecht 1985; Shane 1986). For example, government funds for colonization open up rain-forest regions for settlement and thereby accelerate the rate of deforestation, while government loans to farmers speed up the rate at which farmers convert forests into fields (Hecht 1985). Private investors convert large areas of forest into plantations for the cultivation of export crops; spontaneous colonists follow roads constructed by other investors in pursuit of oil, minerals, or timber. Taken together, these considerations suggest that rapid deforestation coincides with the incorporation of rain-forest regions into an expanding national and world economy. In other words, deforestation occurs as part of a process in which capitalism penetrates the countryside. In some instances, such as the deforestation of Indonesia's outer islands, foreign capital plays a role in the deforestation process (Peluso 1983). While the eventual result of this process may be regional underdevelopment (Bunker 1984), rapid deforestation initially occurs as part of an accelerated expansion in the larger economy (Hecht 1985). Extending this line of argument, some analysts might argue that rapid deforestation has its origins in the classical forms of dependency which tie peripheral nations to the core states in the world system.[2] In this interpretation, rapid deforestation is a by-product of a pattern of trade in which peripheral countries export agricultural commodities and raw materials like timber to the core nations.

In addition to its inconclusiveness on issues of causation, the deforestation literature has been uneven in its coverage of the world's rain-forest regions. Latin America has been well studied, while Africa has received almost no attention. In this context, a cross-national study which includes African, Asian, and Latin American countries promises to add breadth to the depth of understanding available in the case studies. If the same study can provide partial tests of the adequacy of the population-growth and capital-availability explanations for deforestation, it should enhance our understanding of the causes of tropical deforestation.

Data and methods

Data-quality considerations influenced the choice of a data set and the selection of a sample for study. Cross-national data on tropical deforestation are found in two data sets, Food and Agriculture Organization (FAO) production data and data from a FAO-United Nations Environmental Program (UNEP) study (1982). The FAO-UNEP data set seemed more useful for several reasons. First, the FAO-UNEP study used a restrictive definition of deforestation. It measured deforestation as a decline in closed tropical forest areas, while the FAO production data lumps together declines in all types of forests, arid, alpine, as well as tropical.[3] Second, the FAO-UNEP study distinguishes among countries in terms of data quality, while FAO's production reports do not. For these reasons, this study uses FAO-UNEP data. Of the 60 countries containing tropical forests, 36 had data on deforestation which the study's directors regarded as either satisfactory, good, or very good (Lanly 1983:297). This paper analyzes data from these countries. Since the data on deforestation from the remaining 24 countries were poor in quality, these countries were excluded from the study. The methods of data collection varied among the 36 study countries. Satellite imagery, airborne radar, and aerial photography provided estimates for 18, 3, and 4 countries, respectively. The data for the remaining countries (11) came from reliable on-ground surveys of land-use conversion in and around forested areas (Lanly 1983: 296).

The countries in the sample are spread across Africa, Asia, and Latin America in roughly proportional numbers and contain approximately 77 percent of the world's tropical forests.[4] On several measures (the extent of urbanization, rates of economic growth, and rural population growth rates), the included and excluded countries do not differ significantly. The included countries have somewhat larger forested areas and higher GNPs per capita ($792 to $532) than the excluded countries. The sample does have countries with small tropical forests (Burundi, Costa Rica, Guinea-Bissau, Haiti, Jamaica, Rwanda, and Sri Lanka) and low per capita GNPs (Burundi, Guinea-Bissau, Haiti, India, Nepal, Togo, Zaire), so it contains the full range of variation among the variables and can be used to assess their effects on deforestation. In sum, the excluded and included countries are not identical, but the differences between them do not appear to bias the analysis in a serious way.

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[2] Development sociologists frequently contrast classical and new industrial forms of dependency (Evans 1979). As Hecht (1985:673) has pointed out, the newer forms of dependency almost always involve investments by multinational companies in industrial plants in urban areas. Given this pattern of investment, there is little reason to expect a direct relationship between deforestation and the newer forms of dependency.

[3] Closed forests have unbroken canopies; in open forests trees are spread more widely, oftentimes in a prairie setting.

[4] The sample included 16 African countries (Benin, Burundi, Cameroon, Gabon, Gambia, Ghana, Guinea-Bissau, Ivory Coast, Kenya, Liberia, Nigeria, Rwanda, Sierra Leone, Tanzania, Togo, Zaire), 13 Latin American countries (Bolivia, Brazil, Co[illegible]mbia,

The analyses reported below include the following variables:[5]

Deforested area 1976–1980. This variable measures the average annual decline in hectares of a country's tropical forests during the 1976–1980 period. Prior to computing this figure, FAO-UNEP personnel established a uniform system for categorizing forests by their humidity and the density of their canopies (FAO-UNEP 1982). The uniformity established by these definitions makes it possible to cross-nationally compare deforested areas.

Data quality. Each equation contains a variable which measures the quality of a country's data (1 = very good; 2 = good; 3 = satisfactory), as judged by the United Nations' personnel who compiled the data. The inclusion of this variable in each equation provides a control for variations among countries in the quality of the data.

Closed-forest area 1975. There is a necessary relation between the area deforested annually and the extent of tropical forests in a country. Only countries with large- or medium-sized tropical forests will experience the deforestation of large areas each year. To prevent

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Costa Rica, Ecuador, Haiti, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad, Tobago, and Venezuela), and 7 Asian countries (India, Malaysia, Nepal, Papua New Guinea, Philippines, Sri Lanka, and Thailand). The sample excluded 9 African countries (Angola, Central African Republic, Congo, Equatorial Guinea, Guinea, Madagascar, Mozambique, Sudan, and Zambia), 8 Latin American countries (Belize, Cuba, Dominican Republic, El Salvador, Guatemala, Guyana, Honduras, and Surinam), and 7 Asian countries (Bangladesh, Bhutan, Burma, Indonesia, Kampuchea, Laos, and Vietnam).

[5] Data Sources: deforested area-FAO/UNEP, Tropical Forest Resources Assessment Project (1982); closed-forest area-FAO/UNEP, Tropical Forest Resources Assessment Project (1982); rural population growth-U.N., Estimates and Projections of Urban, Rural, and City Populations, 1950–2025 (1985); population growth, 1960–1975-World Bank, World Tables, Vol. 2 (1983–1984); GNP per capita, 1975-World Bank, World Tables, Vol. 2 (1983–1984); wood exports, 1975-FAO, Yearbook of Forest Products (1976); agricultural exports, 1975-World Bank, World Tables, Vol. 2 (1983–1984); data quality-Lanly (1983:308).

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this relationship from confounding other relationships in the analysis, closed-forest area has been included in the equations.

Population growth 1960–1975. This variable measures the impact of urban and rural population growth on tropical deforestation. In this line of reasoning, high rates of urban and rural population growth generate strong demand for agricultural and wood products which, in turn, promotes deforestation.

Rural population growth 1960–1970. Demographic explanations often attribute declines in forest area to growth in the rural populations living near forests (Myers 1984; World Resources Institute 1985). While additional pressure to expand the cultivated area by clearing forests occurs with each birth, the largest declines in forest area occur when a child reaches adolescence. At this point, a family usually claims and clears new lands in order to provide an economic base for a male child; alternatively, a young man may begin taking out contracts to log nearby forests. In both cases, the effect of local population growth on forest clearing lags about 15 years. To capture this effect, the study measures population growth between 1960 and 1970.

GNP per capita 1975. The numerous ways in which the availability of capital promotes rapid deforestation makes it difficult to select a single measure for this effect and suggests that a general measure of the level of economic activity in a country may provide the best measure for this effect. GNP indirectly measures the wealth which provides local capital for activities which spur deforestation, such as logging, mining, and plantation agriculture. GNP measures the economic output which generates public revenues for roads and concessional loans to farmers which accelerate deforestation.

In an attempt to specify the relationship between economic development and deforestation, two additional variables were added to equations containing demographic- and economic-development variables. These variables, export trade in forest products and export trade in agricultural products, provide a preliminary test of the classical dependency explanation for deforestation.

Value, wood exports 1975. Plantations produce only a small fraction of the tropical hardwoods exported to developed countries; most of the exported wood comes from forests which are logged without replanting (FAO-UNEP 1982). For this reason, one would expect a positive relationship between deforestation and the value of foreign trade in tropical hardwoods.

Export agriculture 1975. In a number of well-known instances expansion in export agriculture has spurred tropical deforestation. The expansion of Central American cattle ranches to meet a growing demand for imported beef in the U.S. market entailed the widespread destruction of tropical forests (Shane 1986). If this argument is correct, countries which experienced rapid deforestation during the 1960s and early 1970s should have had larger-than-average agricultural export sectors by 1975. This variable measures the value of all agricultural exports, including wood, as a proportion of gross-domestic product.[6]

The dependent variable, hectares deforested, and several independent variables (closed-forest area, population growth, GNP per capita, and wood exports) have skewed distributions. Because the arguments presented above postulate linear relationships between these variables and deforestation, the skewed distributions could mask the existence of a relationship in the data. To counter this tendency, these variables have been logged (Cohen and Cohen 1975:244–45). To avoid problems of simultaneity bias (Greenwood 1975), all of the independent variables with the exception of the one lagged variable (rural population growth) are taken from 1975 data. The dependent variable concerns the 1976–1980 period.

The analyses of the 36 countries presented below use both weighted and unweighted samples. Because this study attempts to answer questions about global patterns rather than intercountry differences in deforestation, most of the analyses weight cases by the size of a country's closed-forest area—in effect, weighting countries with large tropical forests heavily and countries with small tropical forests lightly. This procedure makes equal units of forest area, belonging in varying proportions to different nations, the unit of analysis.

Findings

Table 1 presents the correlation matrices; Table 2 reports the results from the regression analyses. In diagnostic tests for multicollinearity, the highest condition index achieved by any of the equations is 3.4. Because this score is well below the level at which the effects of collinearity begin to be observed (Belsley et al. 1980:128), it indicates that the equations do not suffer from serious problems of collinearity.[7] Equation 1 in Table 2 indicates that in an unweighted sample, pop-

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[6] The analysis uses a ratio variable in this instance in order to avoid the problems of collinearity which occur with national accounts data when large countries have high scores and small countries have low scores on all measures.

[7] Scores on condition indices have to be above 15 before the effects of multicollinearity can be observed in an equation. The index is calculated from "the eigenvalues of the matrix X'X, where X is the data matrix, divided into the largest eigenvalue" (Kennedy 1985:150). For further details on the method, see Belsley et al. (1980).

Simpler but less precise measures of collinearity also indicate that it is not a problem in these equations. One way to assess the degree of collinearity among the independent variables is to regress each independent variable on the other independent variables (Lewis-Beck 1980:60). Econometricians usually do not worry about collinearity if the r^2 from these equations does not exceed the r^2 in the original analysis (Kennedy 1985:150). In this study, the highest r^2 involving just the independent variables is .58, more than .20 below the r^2 in the regressions on deforestation. Accordingly, collinearity would not appear to be a problem.

Table 1. Means, standard deviations, and zero-order correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Average deforested area, 1976–1980 (thousand hectares)								
(2) Data quality	.965							
(3) Forest area (thousand hectares)	.972	.241						
(4) GNP per capita, 1975	.293	−.049	.425					
(5) Population growth, 1960–1975 (in thousands)	.529	.130	.411	−.131				
(6) Rural population growth, 1960–1975 (in thousands)	.475	.202	.352	−.312	.929			
(7) Value, wood exports, 1975 (thousands, U.S.$)	.544	−.013	.655	.214	.250	.301		
(8) Export average, 1975	−.157	−.260	−.260	−.144	−.132	−.161	.174	
Mean[a]	153.1	2.3	25,964	648	10,184	3,577	47,777	.133
SD	286.6	.8	62,726	758	29,917	13,482	107,294	.109

[a] The means and standard deviations reported here come from an unweighted sample, and they have not been transformed to correct for skewness.

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ulation growth (not GNP per capita) explains substantially the variations in tropical deforestation.[8] An analysis of the residuals found one influential case: Guinea-Bissau. The removal of this case from the analysis in Equation 2 improves the explanatory power of the population growth variable, but otherwise leaves the equation unchanged.

A comparison of the findings from the weighted and unweighted samples of all 36 countries clarifies the relationship between level of development (GNP) and deforestation.[9] GNP explains a substantial amount of variation in the weighted analysis in Equation 3, but it fails to explain much variation in the unweighted analysis in Equation 1. Because the weighted analysis magnifies the importance of countries with large rain forests, this pattern of findings suggests an interaction between the size of a country's forests and the effects of

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[8] Allen and Barnes (1985) found a similar association between population growth and deforestation in a study of arid, alpine, and tropical environments.

[9] As mentioned in the text, there is a close relationship between closed-forest area and the area deforested. Only countries with large rain forests will have large areas deforested each year. Several reviewers expressed concern that the closeness of this relationship could distort the other, more substantive relationships in the analysis. In response to these concerns, I re-estimated the equations using another measure of the extent of forests (the percentage of a country's land area covered by closed forests); this alternate measure does not create the problem noted above of high correlations between large numbers. The equations presented below are re-estimations of Equations 1 and 3 in Table 2, using the new measure of forest area.

Unweighted Analysis:

$$\text{area deforested} = \underset{(2.30)}{-3.85} + \underset{(.313)\text{quality}}{.311\text{data}} + \underset{(.014)\text{extent}}{.046\text{forest}^{**}} + \underset{(.103)\text{change}}{.537\text{population}^{***}} + \underset{(.352)}{.216\text{GNP}^{***}}$$

$r = .775$, $r^2 = .601$, $n = 36$.

Weighted Analysis:

$$\text{area deforested} = \underset{(2.02)}{-4.63} + \underset{(.266)\text{quality}}{.353\text{data}} + \underset{(.011)\text{extent}}{.020\text{forest}} + \underset{(.076)\text{change}}{.601\text{population}^{***}} + \underset{(.186)}{.756\text{GNP}^{***}}$$

$r = .892$, $r^2 = .796$, $n = 36$.

* $p < .05$, ** $p < .01$, *** $p < .001$.

These re-estimations of Equations 1 and 3 suggest that the results of this analysis are quite robust. Despite the change in the measure of forest extent, the patterns in the re-estimated equations do not differ significantly from the patterns in Table 2. Of the 2 measures of forest extent, I chose to present analyses using forest area rather than the percentage of a country in forests because the latter variable is a ratio variable. Given the controversy surrounding the use of ratio variables in regression analyses, it seemed advisable to avoid the use of ratio variables wherever possible. For an excellent review of the ratio variable controversy, see Firebaugh and Glenn (1985).

Table 2. Regression analyses on tropical deforestation

Independent variables	Unweighted analyses (1)	(2)	Weighted analyses (3)	(4)	(5)	(6)
Data quality	.133 (.223)	.049 (.212)	−.354 (.224)	−.460 (.245)	−.357 (.261)	−.260 (.254)
Forest area	.667*** (.093)	.595*** (.092)	.418*** (.105)	.486*** (.113)	.411** (.121)	.450*** (.113)
GNP	−.014 (.235)	.226 (.241)	.520** (.172)	.617** (.214)	.517** (.176)	.555** (.179)
Population growth	.180* (.086)	.344** (.106)	.355*** (.069)	—	.356*** (.072)	.369*** (.071)
Rural population growth	—	—	—	.370*** (.093)	—	—
Wood exports	—	—	—	—	.005 (.083)	—
Agricultural exports	—	—	—	—	—	1.54 (1.92)
r^2 (adjusted =	.772	.808	.830	.790	.823	.828
N =	36	35	36	36	36	36

The numbers in parentheses are standard errors of the B coefficients.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$.

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capital availability on deforestation. Unweighted zero-order correlations between GNP and deforested area for countries with large and small rain forests provide further evidence for this interaction. For the 8 countries with the largest forests, the correlation between GNP per capita and the area deforested is .575; for the remaining 28 countries with smaller forests, the correlation is −.011.

These findings suggest the importance of large, capital-intensive projects in sustaining high rates of deforestation in countries with large forests. Without expensive projects like Brazil's Trans-Amazon Highway to open up distant markets and bridge natural barriers, such as fast-running rivers, rates of deforestation would be much lower in these places. In countries with small, scattered rain forests, encroachment by growing rural populations, with and without capital, leads to deforestation.

Equation 4 examines an alternative line of influence of population growth on tropical deforestation. It substitutes a country's rural population growth for total population growth in the equation. The success of this variable along with total population growth indicates that population growth contributes to deforestation both directly (by increasing the population which clears the land) and indirectly (by increasing the demand for wood products in a country). The foreign economic-influence variables in Equations 5 and 6 fail to explain much variation in the extent of deforestation. Regional differences in the pattern of foreign influence may explain the negative findings.

While exports of wood have accelerated deforestation in Southeast Asia, most African and Latin American countries have experienced rapid deforestation without exporting significant amounts of tropical hardwoods. Similarly, export agriculture may have contributed to extensive deforestation in Central America, but this pattern does not characterize most African or Amazon Basin countries. Taken together, these findings suggest caution in attributing rapid deforestation to relations of dependency between peripheral and core nations in the world system.[10]

Discussion

The analyses presented in Table 2 allow us to assess in a preliminary way the accuracy of the two arguments about the causes of deforestation presented at the beginning of this article. The analyses provide empirical support for the Malthusian idea that population growth contributes to high rates of deforestation. The significance of these demographic variables in both the weighted and unweighted analyses

suggests that all of the various types of countries with high rates of deforestation have recently experienced rapid population growth. The analyses also indicate that political-economic factors contribute to deforestation in a more limited set of circumstances. In countries like Burundi, Rwanda, and Haiti which have small rain forests, growing peasant populations are largely responsible for deforestation, but in countries like Brazil which have large forests, capital investments in frontier regions make possible rapid rates of deforestation.

The last finding raises questions about the extent to which capital expenditures and local population growth interact in the exploitation of forested regions. In some places, deforestation is an extractive process prompted by increasing global demands for timber, and population growth plays a minimal role in the process. In other places, population growth alone causes deforestation. In still other places, capital expenditures and population growth interact in creating conditions which accelerate deforestation. Governments or private investors spend money on infrastructure, such as roads which open up regions for settlement and deforestation. Questions about the form and prevalence of these different deforestation processes can only be answered through comprehensive, comparative studies which focus on regional and subregional dimensions of deforestation both within and across nations.

The finding about capital investment and deforestation suggests that the efficacy of policies designed to preserve tropical forests will vary with the size of the forest. Political pressures on lending organizations like the World Bank—which provide capital for dams, mines, and penetration roads—should slow deforestation in countries with large rain forests because the forested areas cannot be opened up for development and deforestation without major expenditures of capital. Conversely, in countries with small forests, encroachment by the populations surrounding the remaining islands of forest appears to be sufficient to generate high rates of deforestation. To preserve these forests, conservation groups or the state may have to purchase the land, either outright or through debt-for-nature swaps. By denying poor, rural populations access to land, these policies raise important issues of equity (Fortmann and Bruce 1988:273) which policymakers and researchers will want to acknowledge in evaluating the policies.

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[10] I do not present the results from the inclusive model because the inclusion of all of the variables in a single equation would violate the principle that there should be substantially more cases than degrees of freedom in a model. The rule of thumb in multivariate analyses calls for no more than one variable for every eight-to-ten cases (Andrews et al. 1973:27–8; London 1987:35).

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